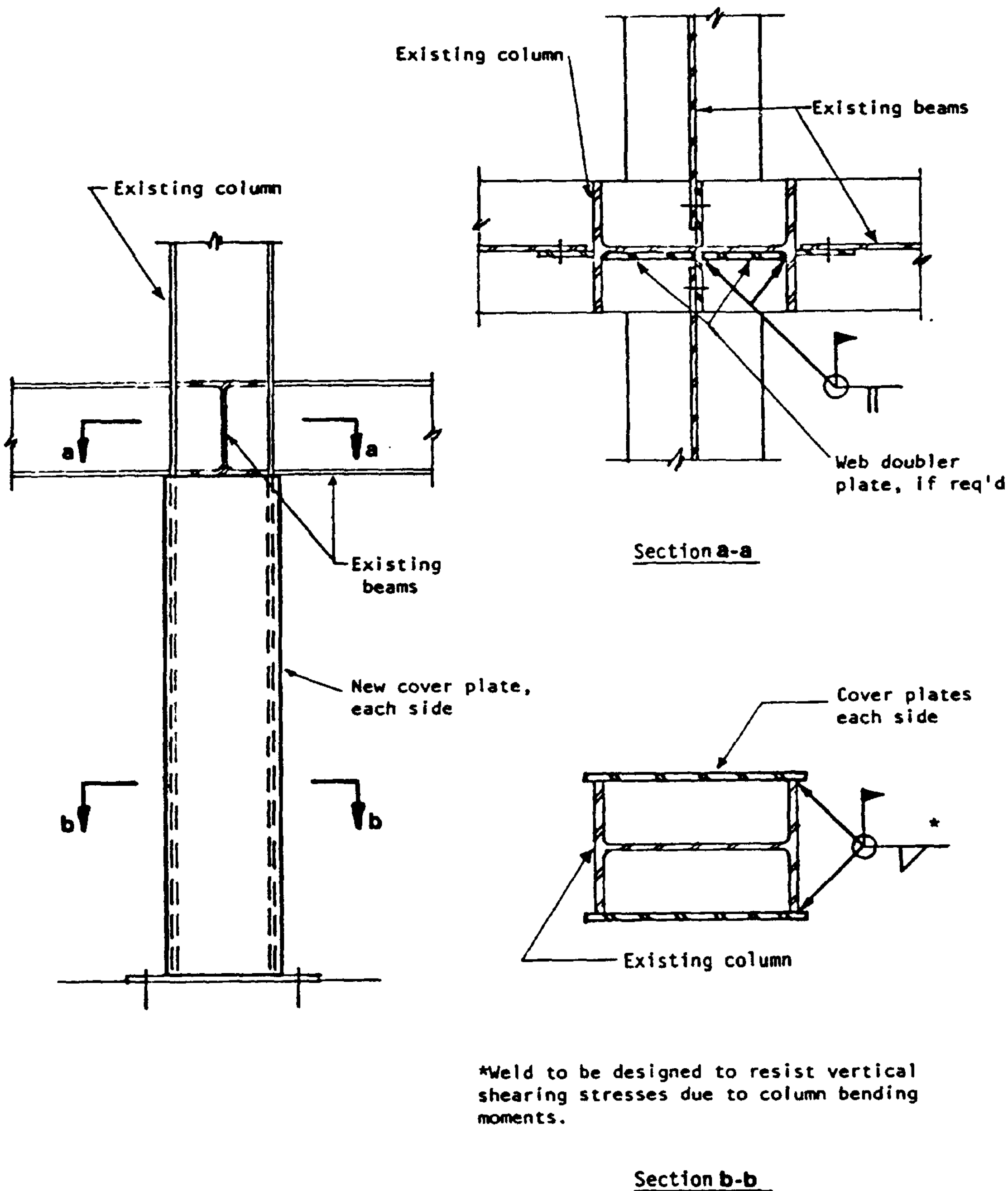


Figure 6–2. Strengthening of existing columns

formed and poured in place or may be placed by the pneumatic method. Paint or other finish on the existing concrete surfaces will be removed and the existing concrete lightly sandblasted to improve the bond of the new concrete.

2. If the identified deficiency exists only in the connecting beams, consideration will be given to acceptance of some minor damage in the form of cracking and/or spalling by repeating the structural evaluation with the deficient beams modeled as pin-ended links between the piers. If this condition is unacceptable, the beams will be removed and replaced with properly designed reinforced concrete as indicated in figure 6-8. An alternative to the above procedures is to fill in selected openings with reinforced concrete as indicated in figure 6-9. The number and location of the openings to be filled in with concrete will depend on functional and architectural as well as structural consideration. If none of the above alternatives are feasible or adequate to ensure the proper performance of the wall, the wall will either be removed and replaced with a new wall that complies with the criteria in chapter 5 or will be supplemented by the addition of new structural elements, as described in paragraph 6-4*d*, that

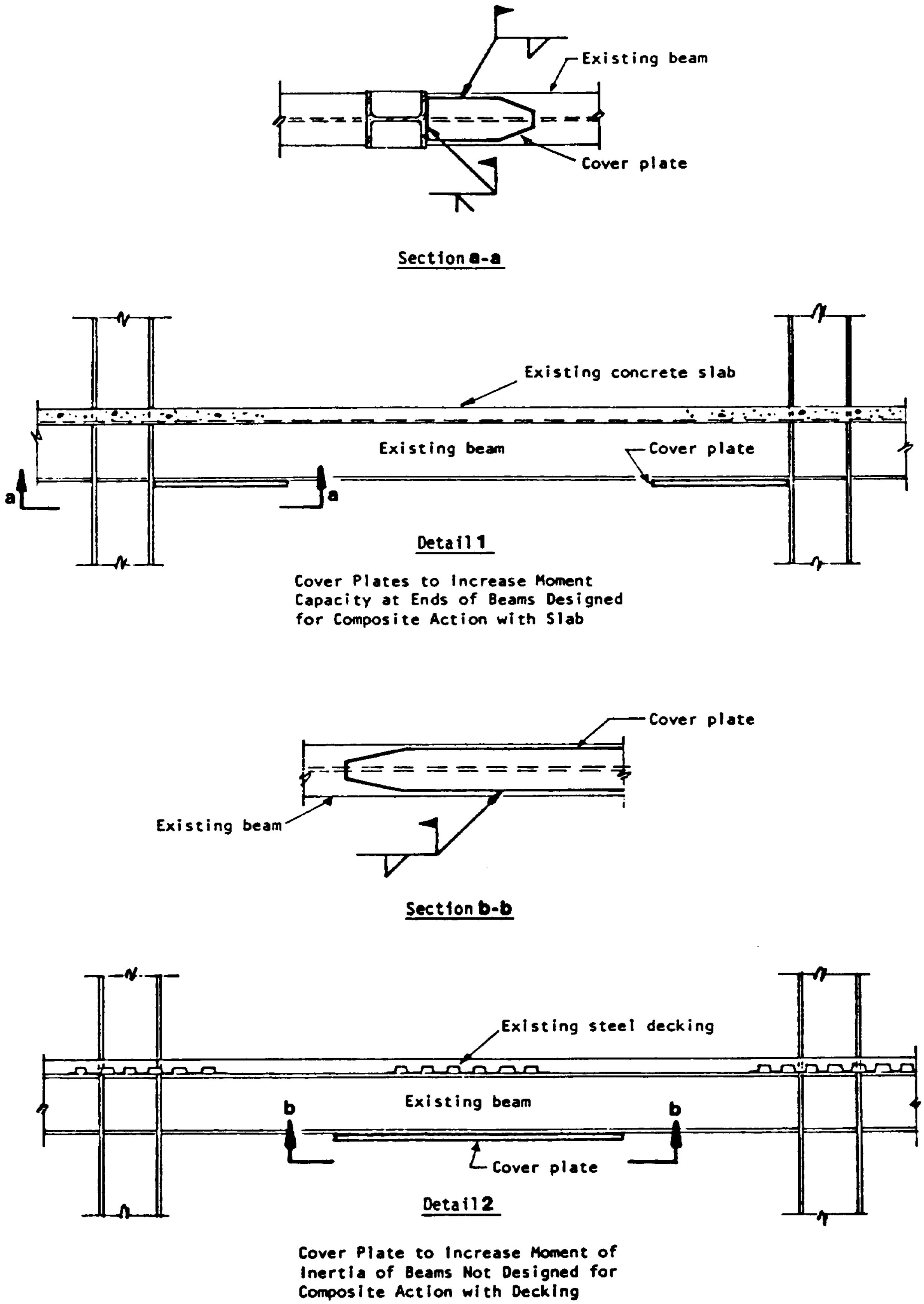
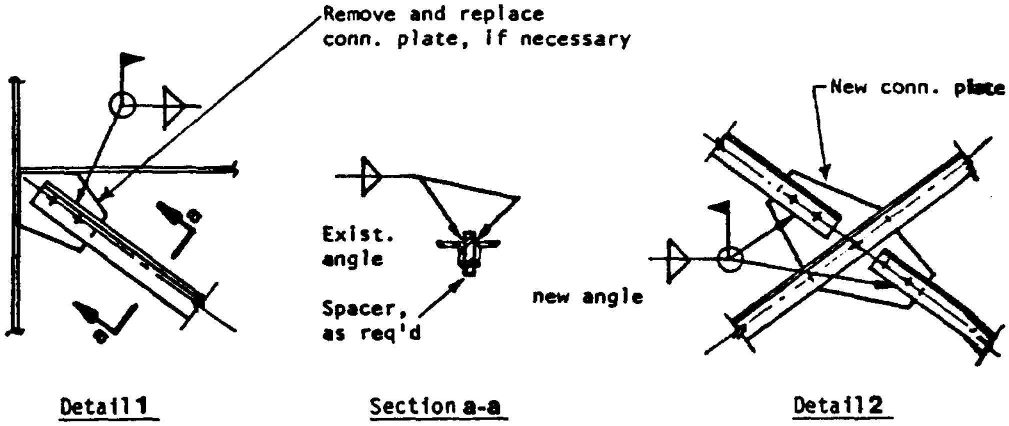
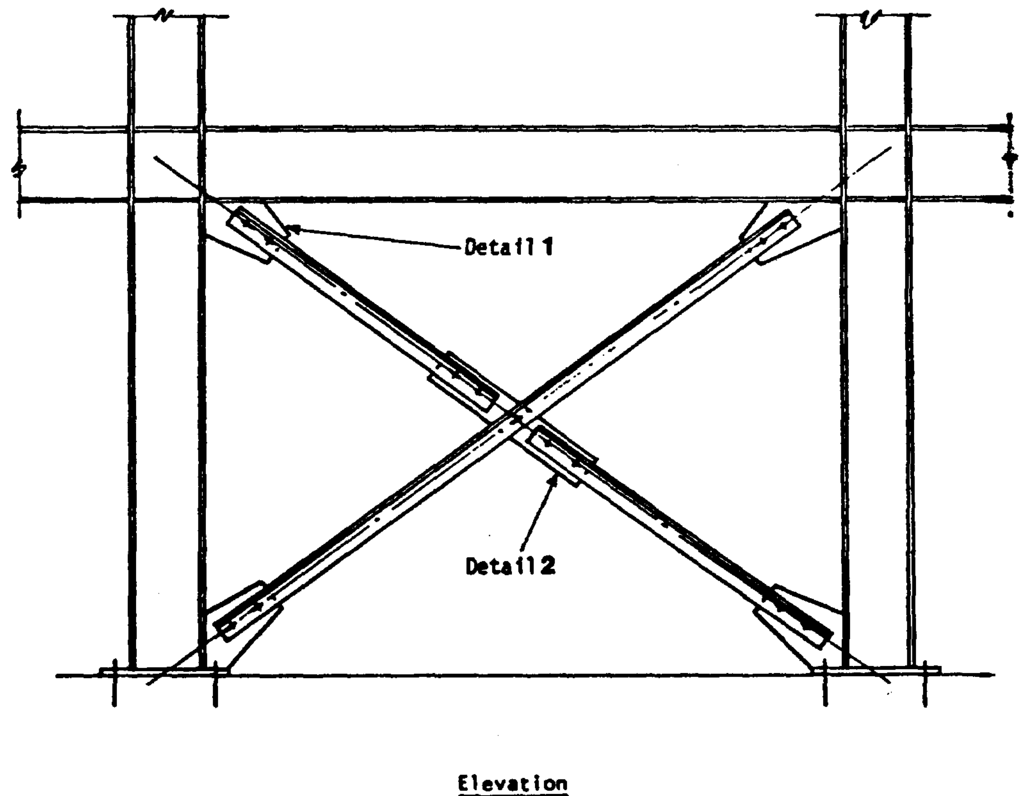


Figure 6–3. Strengthening of existing beams



Upgrading of Single Angle Bracing to Double Angle Bracing



Existing Single Angle Bracing

Figure 6–4. Strengthening of existing bracing

will reduce the forces on the existing wall to acceptable limits.

(b) Walls without openings. Existing reinforced concrete walls or piers without openings can be strengthened by the addition of reinforced concrete on one or both sides as described above for walls with openings and as indicated in figure 6-7.

(4) *Unreinforced concrete or masonry walls or piers.* Unreinforced concrete or masonry walls or piers that do not comply with the acceptance criteria prescribed in chapter 5 will be strengthened or will have the seismic demand forces that they are to resist reduced by the addition of new

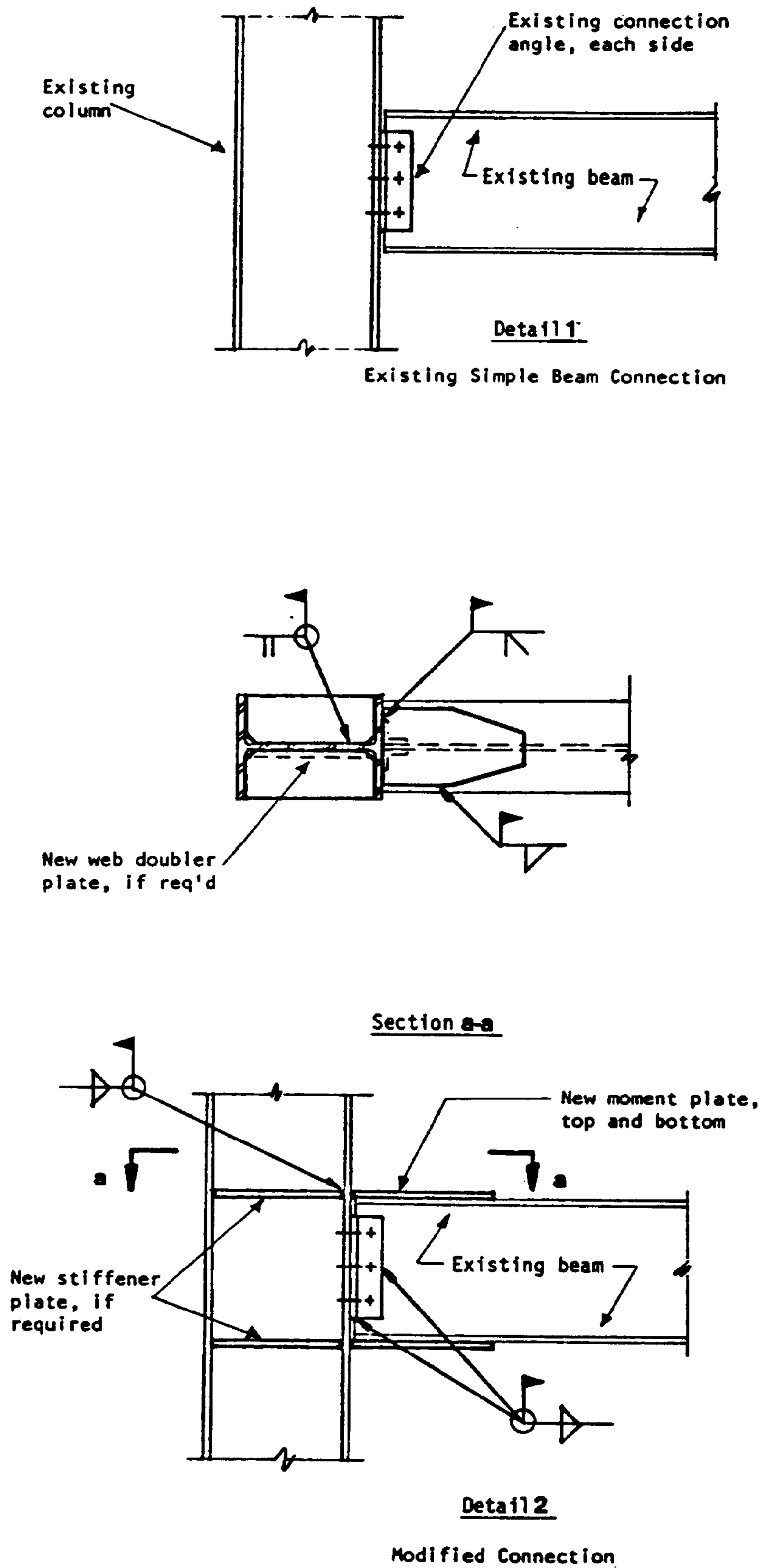


Figure 6–5. Modification of an existing simple beam connection to a moment connection

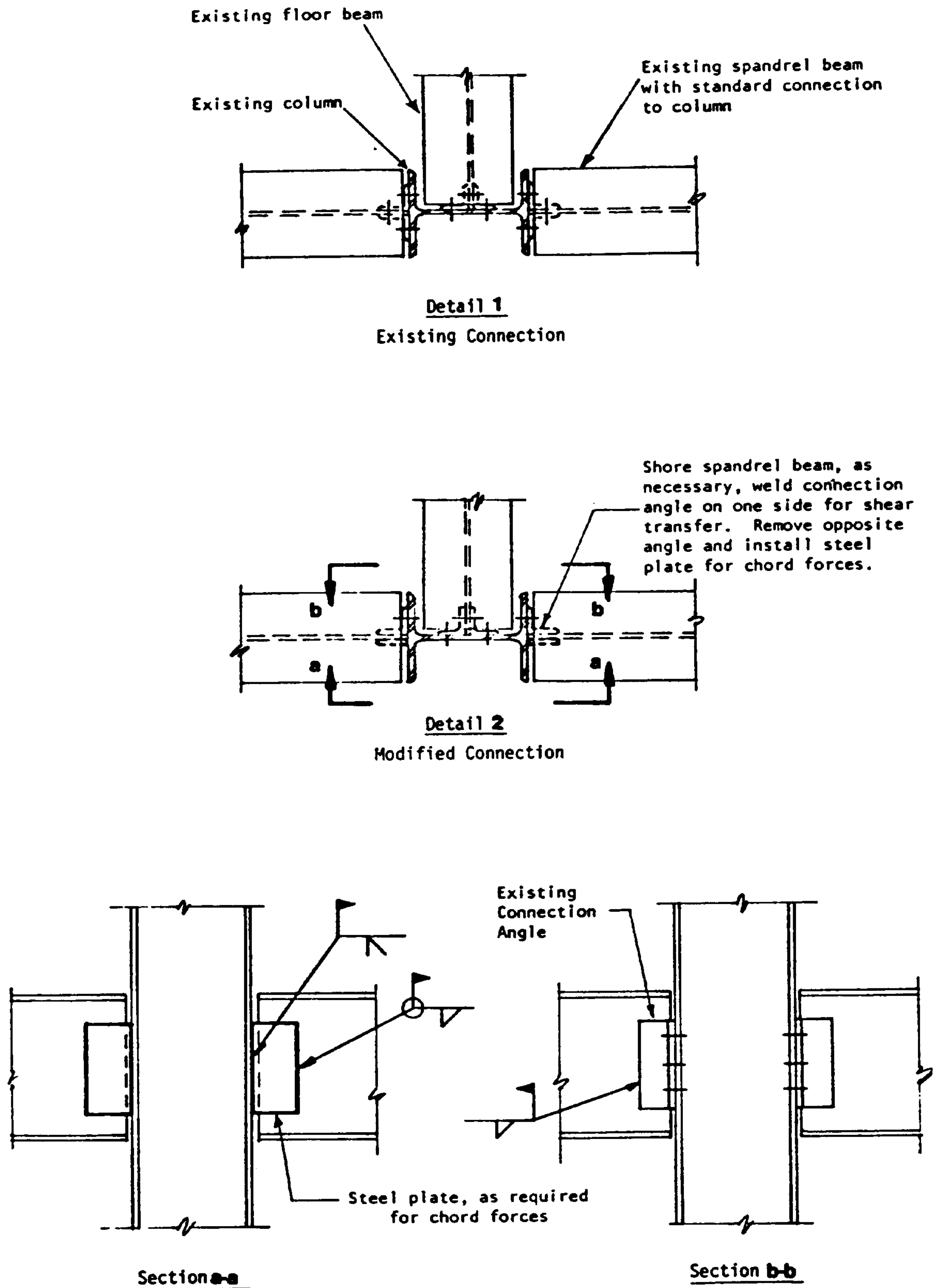


Figure 6–6. Modification of existing steel framing for diaphragm chord forces

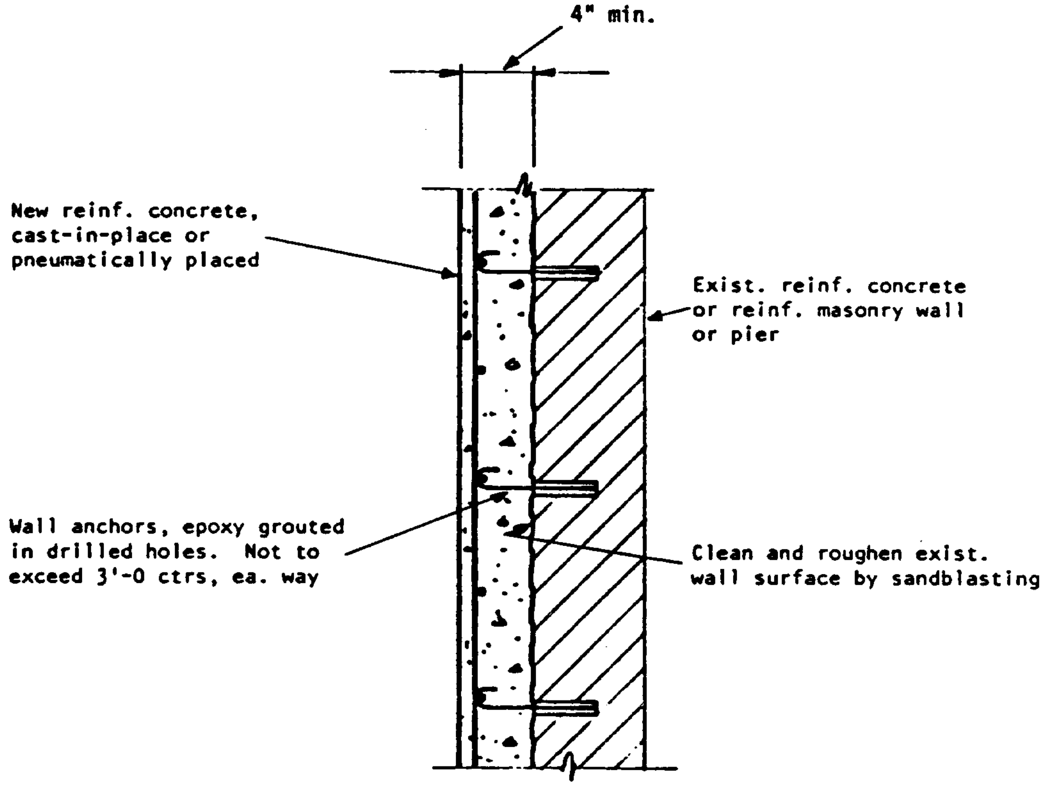


Figure 6–7. Strengthening of existing reinforced concrete or masonry walls or piers

structural elements as described in paragraph 6-6*d*. The strengthening procedure can be similar to that indicated in figure 6-7 for reinforced concrete or masonry. For unreinforced brick masonry walls consisting of four or more wythes of bricks (16 to 18 inches) in thickness, it may be advantageous to remove two or more wythes prior to the addition of the reinforced concrete section as indicated in figure 6-10. This procedure has the advantage of reducing the seismic mass as well as reducing the additional loads on the foundation. For perimeter walls, this procedure is most easily accomplished on the exterior face of the existing wall; however, if the building has historical significance or if the exterior face must be preserved, the procedure can be accomplished on the interior face. Strengthening the interior face of the existing wall will introduce complication because of slabs, beams, or other structural elements framing into the wall that may require temporary shoring, but it will facilitate anchorage of the wall and provide chords for the floor or roof diaphragms as indicated in figure 6-10.

(5) *Timber construction.*

(a) Heavy timber construction. The seismic capacity of existing heavy timber construction may be upgraded by the use of diagonal bracing or knee braces. The diagonal braces may be either timber or steel and are designed for both tension and compression forces. Figure 6-11 indicates typical details for timber bracing. Knee bracing of existing timber framing may be adequate for moderate seismic forces that can be resisted by the resulting knee braced frame with the columns assumed to be pin-ended. The resulting horizontal shear at the base of the columns must be investigated to determine the need for additional connections to transfer the shear to the floor diaphragm or foundation as indicated in figure 6-12.

(b) Wood stud wall. Existing wood stud walls in one- and two-story residential or similar construction can be upgraded with 1 x 6 or 2 x 6 let-in bracing as indicated in figure 6-13. The capacity of this bracing will generally be governed by the effective number of nails that have been driven with allowable spacing and end and edge distances. For heavier lateral loads, plywood sheathing of existing stud walls is an effective procedure for providing the necessary resistance. Figure 6-15 of the BDM provides allowable shear values for plywood shear walls. These values may be increased by the ratio of 1.70/1.33 for compliance with the acceptance criteria of chapter 5. Figure 6-13 from the BDM provides similar allowable shear values for various materials other than plywood. These values may also be increased by the above ratio. Other useful design data and typical connection details for wood stud shear walls are contained in chapter 6 of the BDM. Although the BDM data is applicable to code level

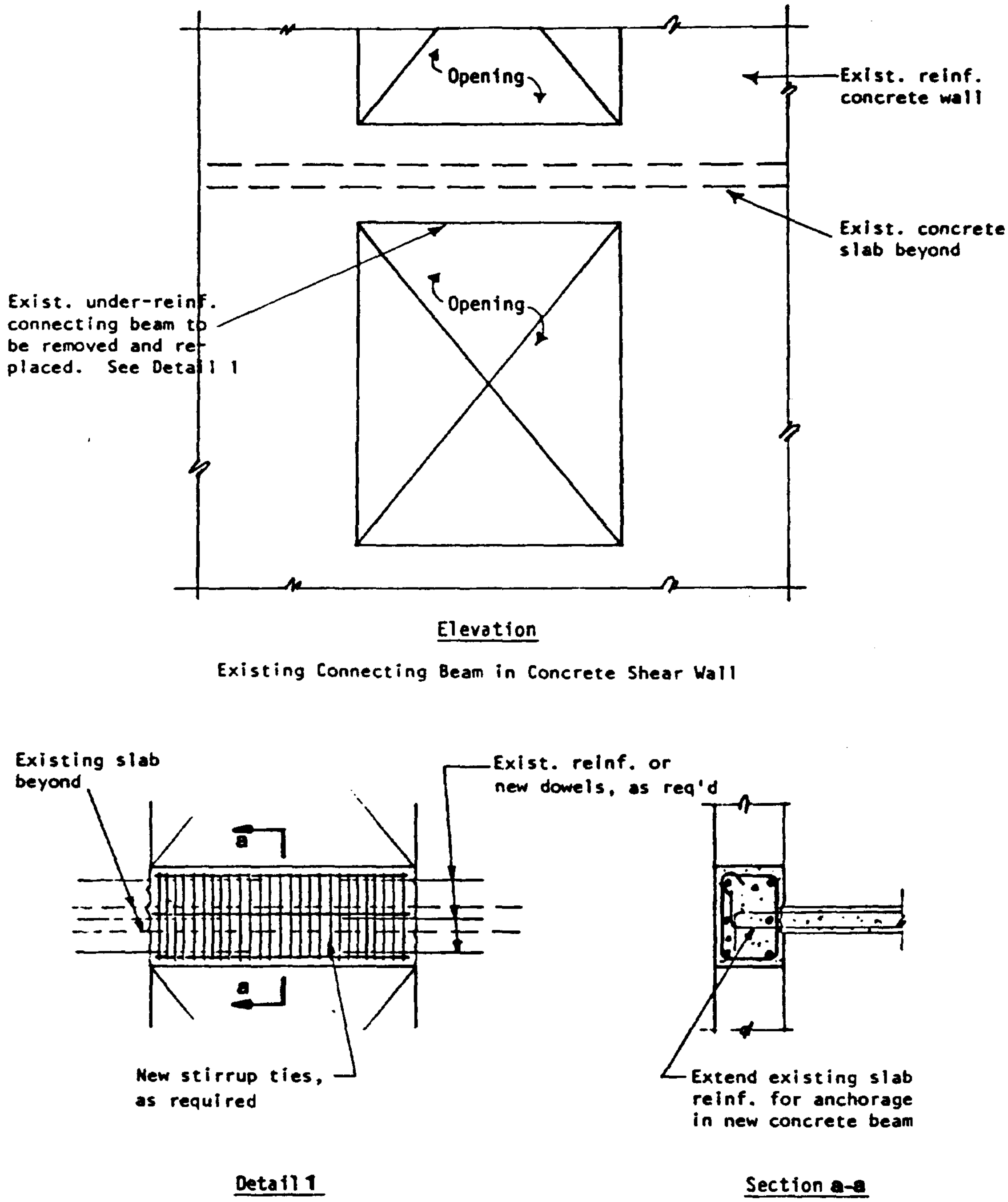


Figure 6–8. Strengthening of existing connecting beams in reinforced concrete or masonry walls

stresses for new construction, similar details with the increased stresses prescribed in the SDG are suitable for seismic upgrading of existing wood stud walls.

(6) *Steel stud walls.* Existing steel stud walls can be upgraded by bracing in the plane of the wall. Typical details are provided in figures 6-17a and 6-17b of the 13DM. The indicated details provide a capacity of 1000 lbs for code level forces (allowable stress plus a one-third increase). This capacity may be increased by 1.70/1.33 for yield level capacity.

(7) *Diaphragms.*

(a) Wood floor framing. Typical details for wood diaphragms are provided in chapter 5 of the BDM. When the seismic evaluation indicates that the existing floor or roof system is inadequate for the necessary diaphragm action, the seismic capacity of the existing system can be upgraded by means of a plywood overlay. The existing floor or roof covering will be removed so that the plywood can be applied to the existing subfloor or roof

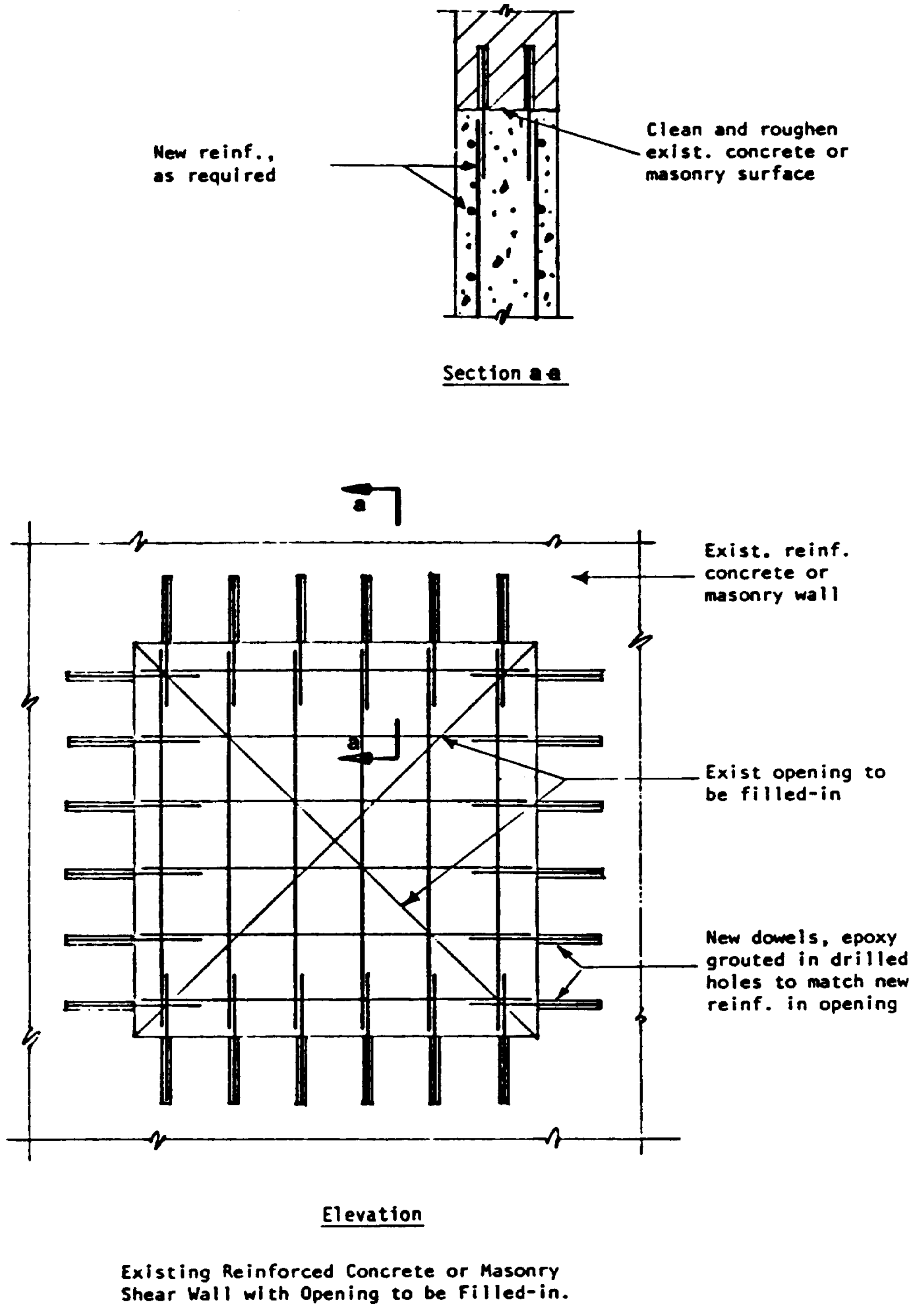


Figure 6–9. Strengthening of existing reinforced concrete or masonry walls by filling in of openings

sheathing. In some cases it may be desirable to remove the subfloor or sheathing to facilitate the installation of the necessary blocking and other connections similar to those shown in figures 5-33 and 5-34 of the BDM. The upgraded diaphragm needs to be evaluated for its capacity to distribute the seismic shear forces to the vertical resisting elements below and also for its capacity to provide resistance to the out-of-plane seismic forces on the exterior walls. The horizontal deflection of wood diaphragms will be checked, in accordance with the provisions of chapter 6 of the BDM, to preclude excessive out-of-plane deformation of masonry or concrete walls. Table 5-6 in the 13DM provides allowable shear forces for horizontal plywood diaphragms. These values are to be increased by 1.70/1.33 for the determination of capacity at yield. The diaphragm must also be able to resist

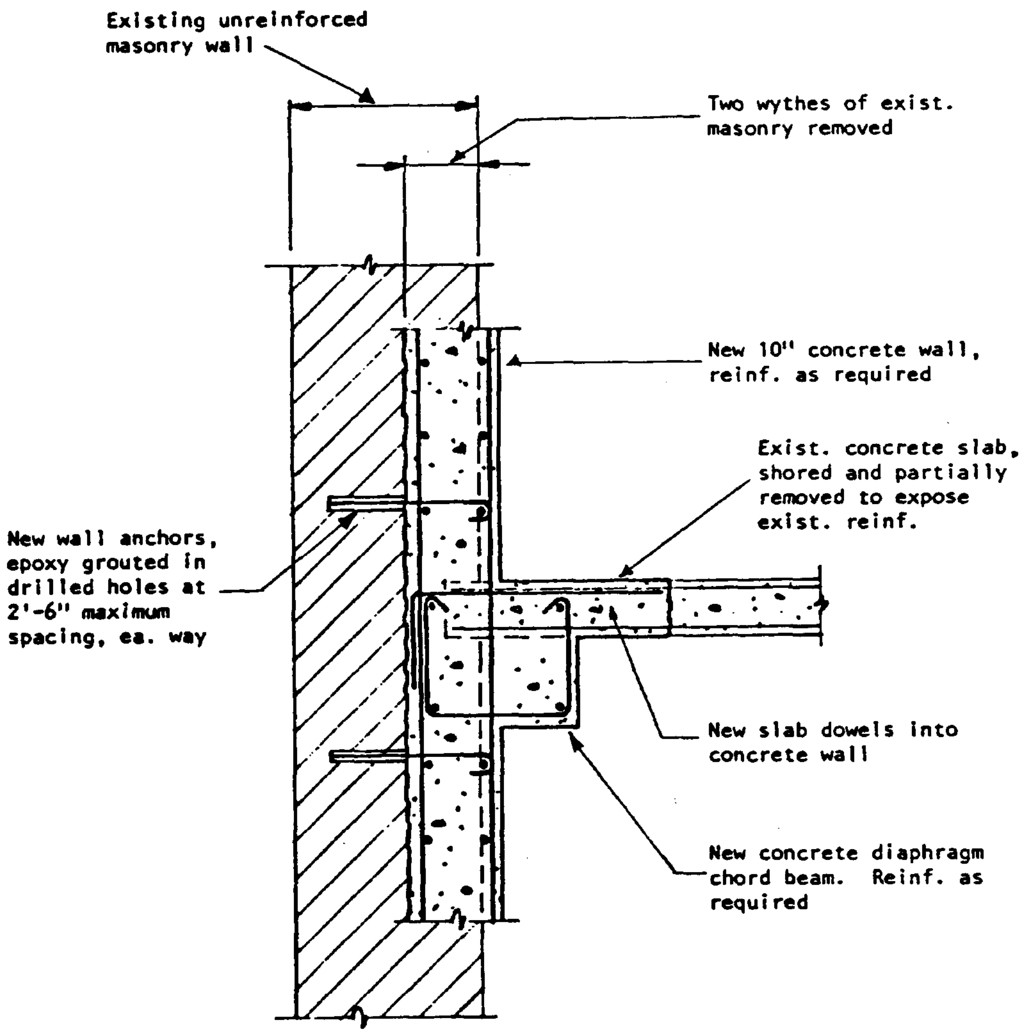


Figure 6–10. Strengthening of existing unreinforced masonry walls or piers

the chord stresses generated by the inertia loads on the diaphragm as it spans horizontally between the vertical resisting elements. Figure 6-14 indicates a detail whereby a continuous steel angle can provide all of the above functions for a wood diaphragm at a reinforced masonry wall. Figure 6-15 indicates details for strengthening of wood diaphragms in steel frame buildings.

(b) Concrete floor or roof systems. An existing concrete floor or roof system can be seismically upgraded for diaphragm action by the addition of a superimposed diaphragm slab as shown in figure 5-8 of the BDM. Figure 6-16 shows a detail of a superimposed diaphragm slab at an existing masonry wall. Diaphragm chords for upgraded concrete diaphragms can be provided or supplemented by continuous steel angles similar to the detail in figure 6-14. An alternative procedure is to form the chord with a new reinforced concrete beam as indicated in figures 6-16 and 6-17. Large openings in existing concrete diaphragms should be investigated to confirm that excessive shear or flexural stresses will not cause distress to the adjacent areas of the diaphragm. Figure 6-18 indicates how additional reinforcement in the superimposed diaphragm slab can be used to provide supplementary trim bars for openings. An alternative procedure for reinforcement of diaphragm openings is to form a reinforced concrete beam around the perimeter of the opening. An additional alternative is to protect the opening with welded structural sections forming a frame for the opening and anchored to the concrete. Inadequate shear transfer from an existing concrete diaphragm to steel framing can be upgraded with shear studs similar to those in figure 6-19 except that the studs would be welded and grouted in holes cored in the existing slab.

(c) Steel decking. The seismic capacity of existing steel decking may be updated, in place, only when it does not have a concrete fill slab or when the fill material can be readily removed. If the above condition is met, the deck can be upgraded

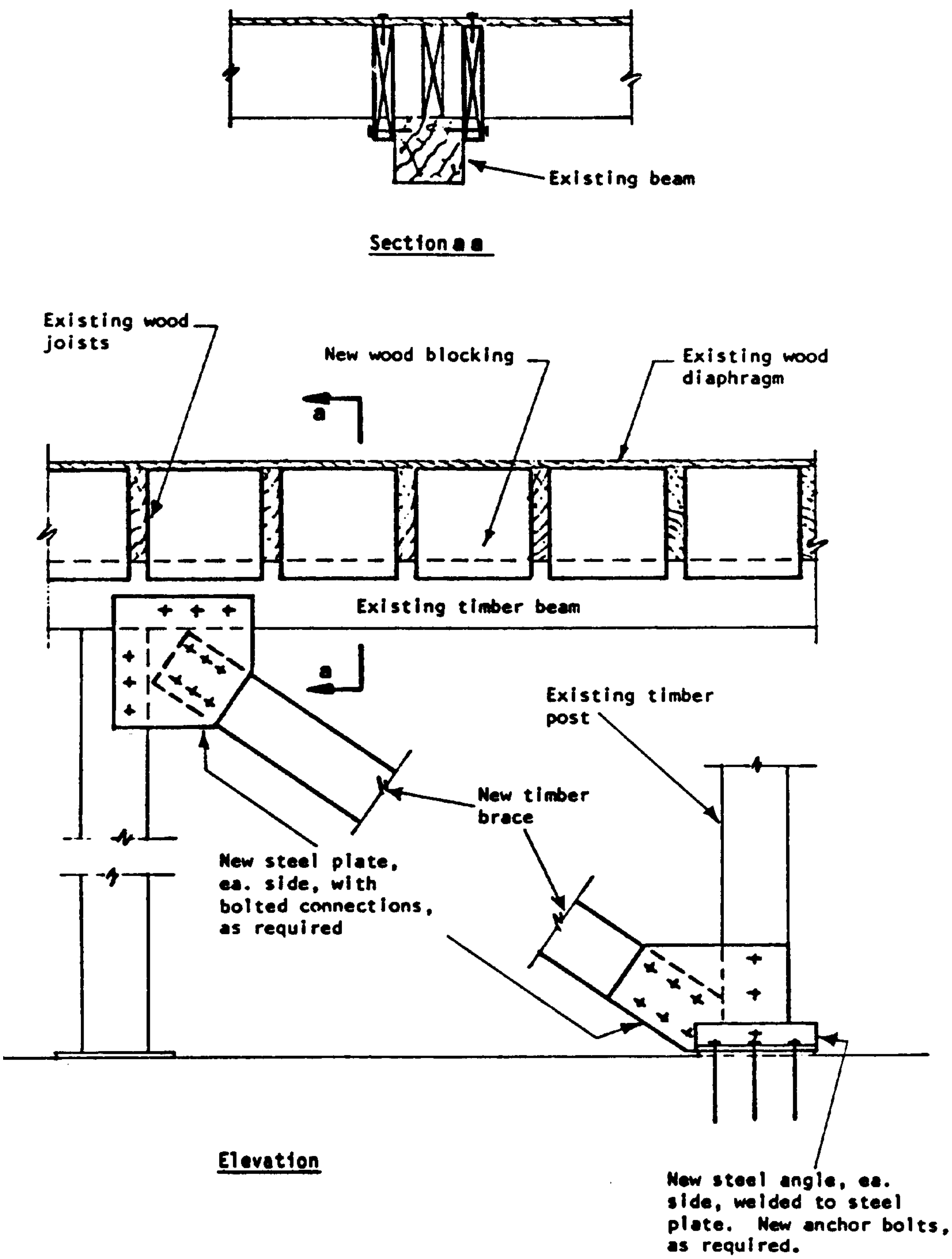


Figure 6–11. Bracing of heavy timber construction

to its maximum capacity by additional welding in accordance with the details indicated in chapter 5 of the 13DM. Additional capacity, if required, can be provided by a reinforced concrete fill as indicated in figure 6-19. If the existing steel decking has a concrete fill, but the composite assembly does not have adequate capacity, additional capacity can be provided by a superimposed diaphragm as is indicated in figure 6-16 for an existing concrete slab.

(8) *Foundations.* Strengthening of existing foundations is generally an expensive and disruptive procedure. If the existing foundations are deficient because of the additional seismic loads required by the provisions of this manual, it will usually be more cost effective to reduce the seismic loads on the existing foundations by redistribution of the lateral loads to other new or strengthened resisting elements.

(a) Spread or strip footings. The bearing

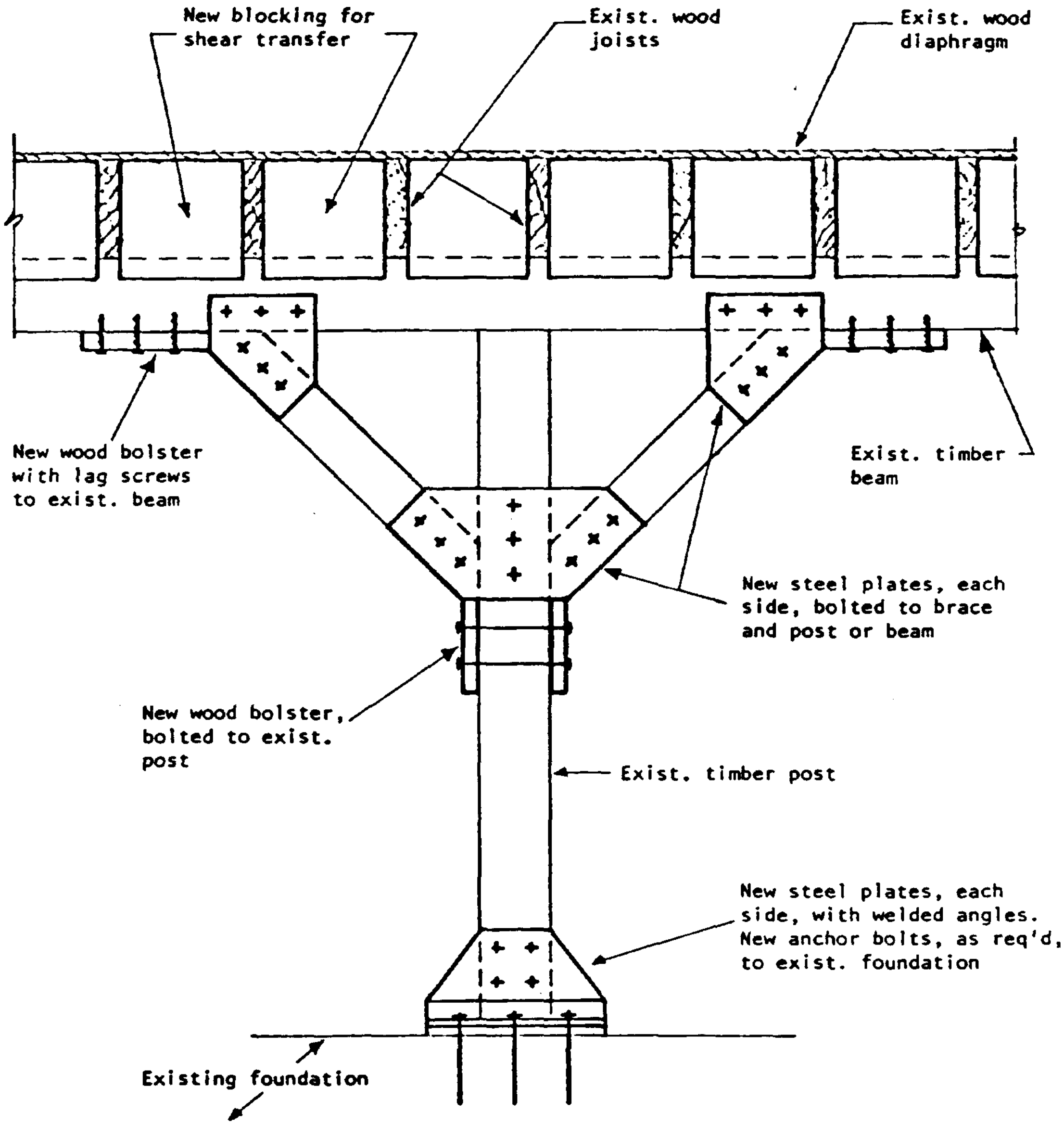


Figure 6–12. Knee bracing of heavy timber construction

capacity of existing strip footings can be upgraded by underpinning as indicated in figure 6-20. The underpinning is performed in spaced segments with the strip footing and wall above providing the rigidity to distribute the loads to the remaining portion of the foundation. As each section of the new foundation is completed and cured it is preloaded by jacking against the existing foundation. When all sections are complete, the space between the new and existing footing is drypacked with nonshrink grout and the jacks are removed and their accesses are also drypacked. Similar procedures can be used to upgrade the capacity of a spread footing. The procedure is only practicable for very large spread footings where a reasonable segment can be undermined and underpinned without significant impairment to the stability of the existing footing.

(b) Piles or drilled piers. The capacity of an existing pile or drilled pier foundation can be upgraded by the addition of additional piles or drilled piers. This will usually require removal and replacement of the existing pile or pier cap and temporary shoring of the column or other element supported by the foundation. Figure 6-21 indicates a typical detail for a pile foundation supporting a steel column.

c. Replacement of existing deficient structural members. Upgrading of deficient structural members by removal and replacement with larger or stiffer members or systems is a feasible, but not always cost effective, rehabilitation procedure. The replacement procedures are essentially the same as those described in paragraph 6-6*d*. The removal

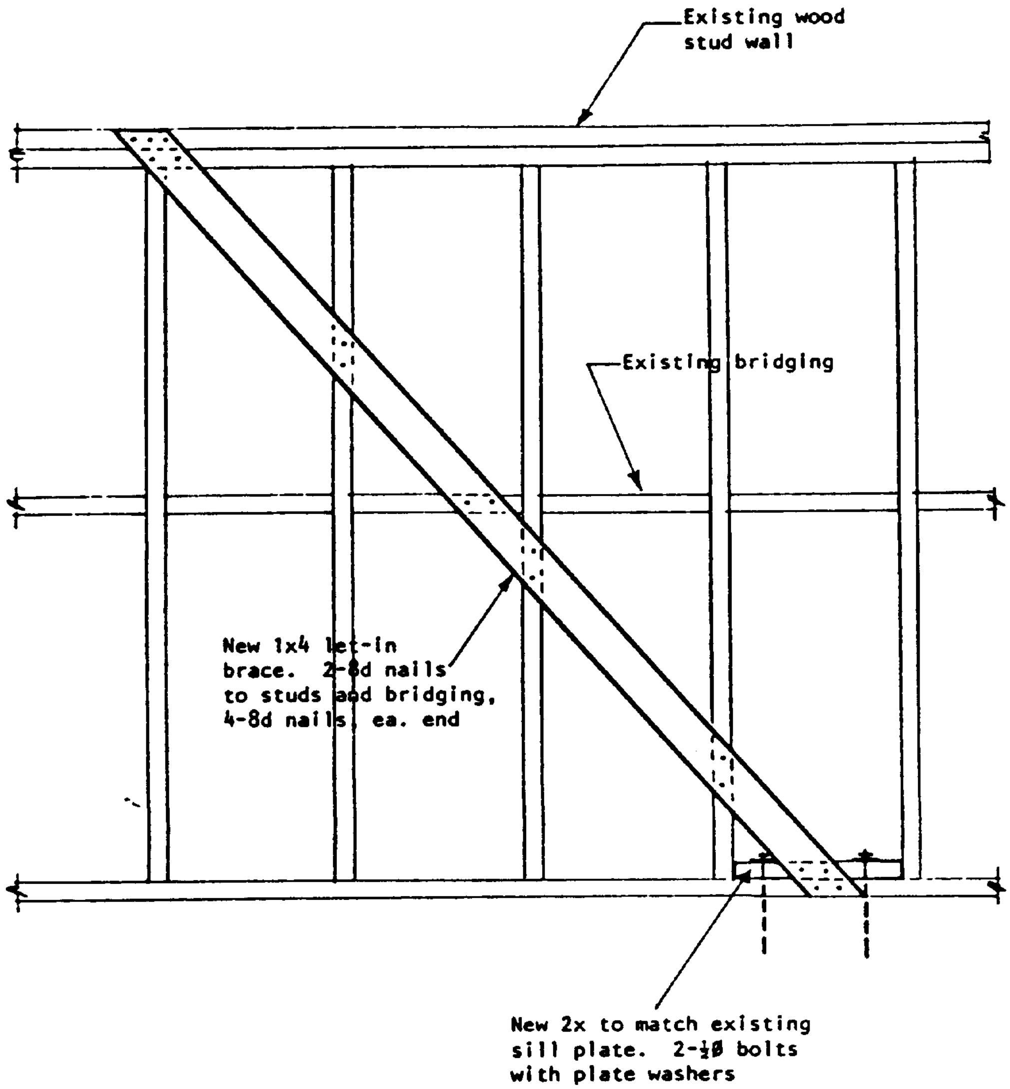


Figure 6–13. Strengthening existing wood stud walls with let-in bracing

procedures must be carefully planned and monitored so as to avoid disturbing construction which is to remain and to provide for proper connections to the replacement construction. This may require temporary shoring or other means of support for the existing construction to remain and careful sequencing of the removal and replacement of the deficient structural members. Figure 6-22 describes the removal of an existing unreinforced masonry wall and replacement with a reinforced concrete wall.

d. Addition of new structural members.

(1) *Rigid frames.*

(a) External frames. Existing buildings whose lateral force resisting system consists of moment frames that do not comply with the acceptance criteria of chapter 5 may be strengthened by the addition of supplementary external rigid frames of reinforced concrete or structural steel. The effectiveness of this procedure depends on providing new frames of adequate strength and rigidity to reduce the forces and deformation of the existing frames to acceptable limits. The costs associated with this strengthening technique may exceed those for more conventional procedures (e.g., addition of shear walls or bracing); however, a significant advantage of this procedure is that it minimizes disruption of the existing facility as most of the required construction is outside of the building. An adequate existing diaphragm is required, but the system can provide the necessary chord capacity as part of the new frame. Typical details for a supplementary steel frame are shown in figure 6-23.

(b) Interior frames. Supplementary interior frames may also be used to reduce the seismic forces and distortions of existing framing. The design and construction procedures for new interior frames in an existing building are similar to those for the removal and replacement of existing deficient structural members as described in paragraph 6-4*c*.

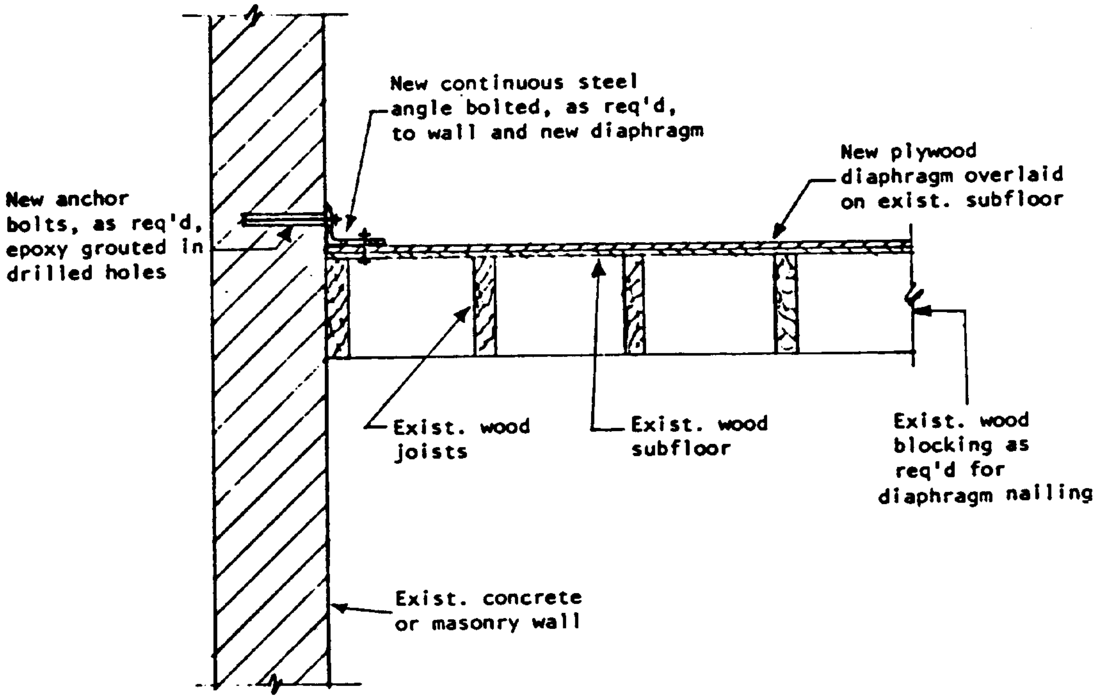


Figure 6–14. Strengthening of existing wood diaphragms in reinforced masonry buildings

(2) *Shear walls.*

(a) Exterior shear walls. The addition of new exterior shears to a seismically deficient existing building is often an attractive alternative because it minimizes disruption of the internal functions of the building. In wood framed buildings the shear walls could be wood stud shear walls or reinforced masonry shear walls depending on the magnitude of the seismic forces to be resisted and the relative costs of the walls and their attendant foundations and connections. In steel framed buildings or reinforced concrete or masonry buildings, the new shear walls will be either reinforced concrete or reinforced masonry. Figure 6-24 indicates the addition of a new reinforced concrete shear wall in an existing reinforced concrete frame building.

(b) Interior shear wall. The addition of new interior shear walls in an existing building may be seriously constrained by the need to maintain an essential function during the construction period. To minimize interference with the functional operations, it may be necessary to consider alternatives that may be more expensive in terms of material and installation costs, but which will minimize the construction time and the disruption of operation within the building. Steel shear walls have been successfully installed under such conditions as indicated in figure 6-25. Prefabrication of the walls is utilized to the maximum extent possible and temporary dust barriers are installed to protect adjacent functions in the building. In buildings that do not have the above constraints, more conventional alternatives, similar to those described in paragraph *(a)* above, may be more suitable. Although it is usually desirable to locate the new shear walls along frame lines (i.e., framing into existing columns and beams) to provide boundary members; to provide dead loads to help resist overturning forces; and to take advantage of existing column foundations, other considerations may dictate wall locations away from the existing frame lines. This condition is illustrated in detail 1 in figure 6-24. Except for very thick slabs, this detail will probably require supplementary members, such as the steel angles shown in the detail, to set as collector members extending beyond the shear wall to facilitate transfer of the diaphragm shear from the slab to the shear wall.

(3) *Vertical bracing.* The addition of new vertical steel bracing is usually a cost effective procedure for upgrading the seismic resistance of an existing steel frame building. The new bracing may be installed to supplement existing bracing or to reduce the seismic forces and displacements of existing moment frames. In low-rise buildings (less than about 6 stories) with average site conditions, the addition of bracing to a moment frame structure will usually mean an increase in the spectral seismic demand as the greater stiffness of the bracing will almost ensure that the building will respond at the maximum amplification of the response spectrum. Also, because of the greater relative rigidity of the bracing, it will usually be required to resist a larger share of the seismic forces than the moment frames. Concentric bracing may be diagonal bracing, x-bracing, or k-

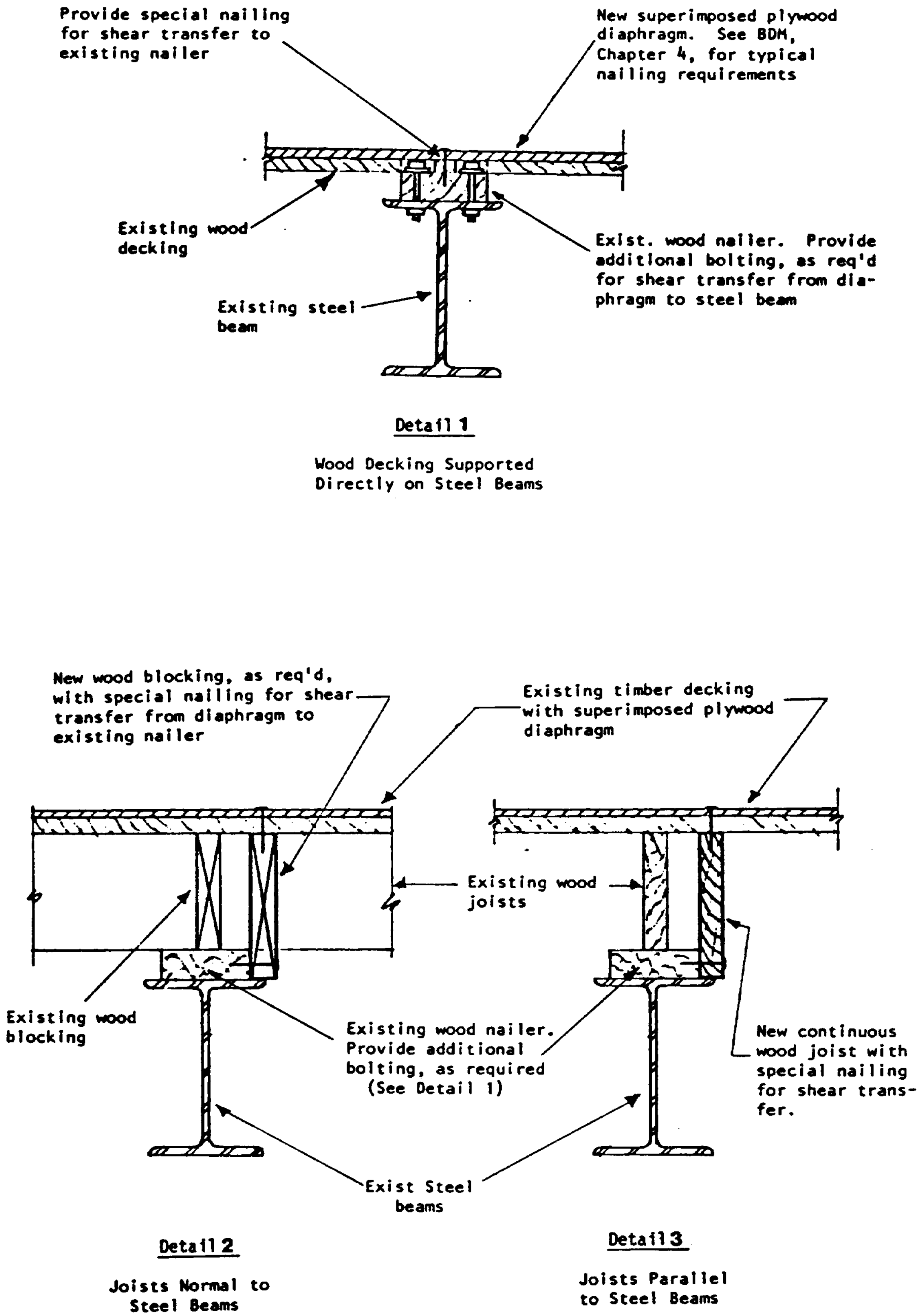


Figure 6–15. Strengthening of existing wood diaphragms in steel frame buildings

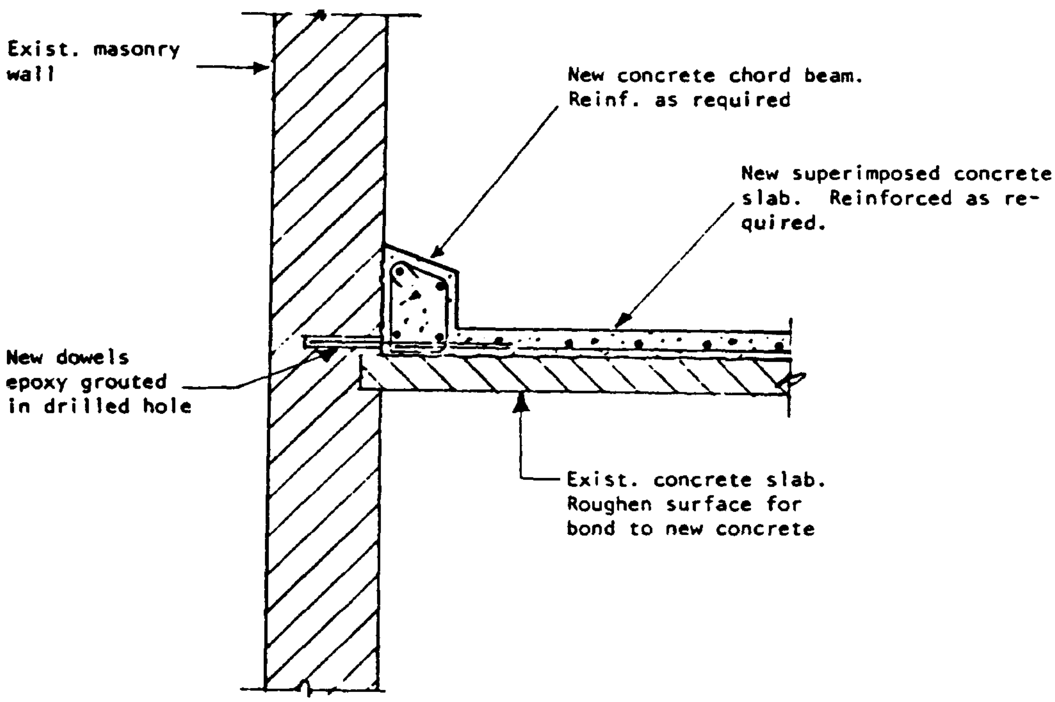


Figure 6–16. Superimposed diaphragm slab at an existing masonry wall

bracing and is usually designed to act both in tension and compression. In recent years eccentric bracing has been promulgated as a means to provide the strength and stiffness of bracing with much of the ductility associated with moment frames. Figure 6-26 indicates typical details for eccentric bracing. In the determination of the type, members, and location of additional braced bays in an existing building an important consideration is the cost associated with the required modification or strengthening of the columns, beams, and foundations as a result of the new bracing. Some of these costs may be significantly greater than the bracing itself so that the use of additional braced bays may be justified if the forces can be reduced so as to eliminate costly modification of the existing structural system.

(4) *Horizontal bracing.* A horizontal structural

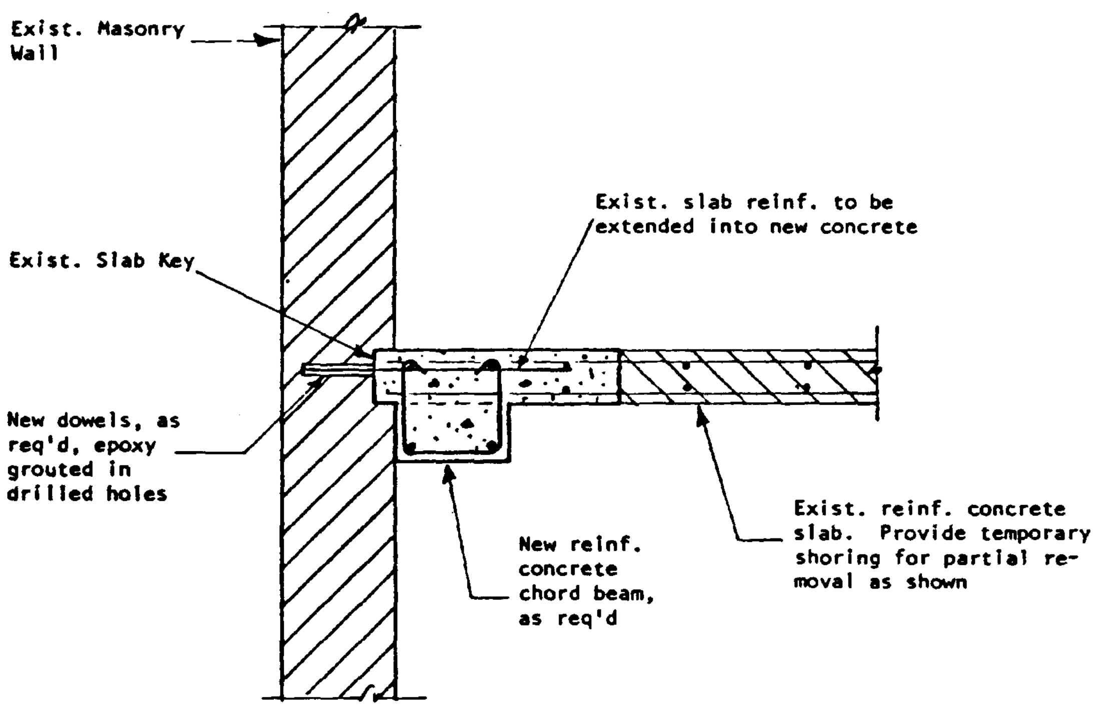


Figure 6–17. Diaphragm chord for existing concrete slab

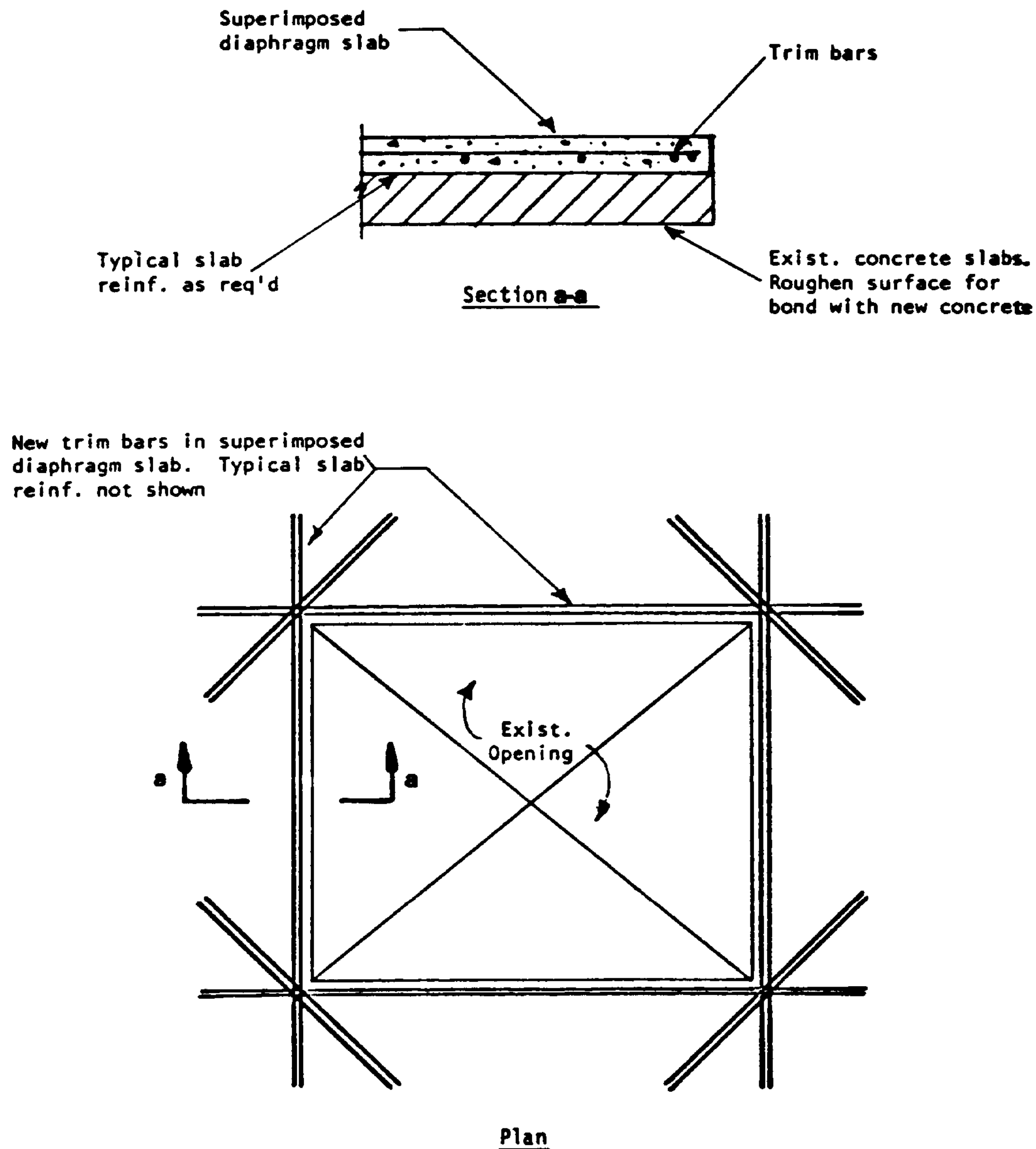


Figure 6–18. Strengthening of openings in a superimposed diaphragm

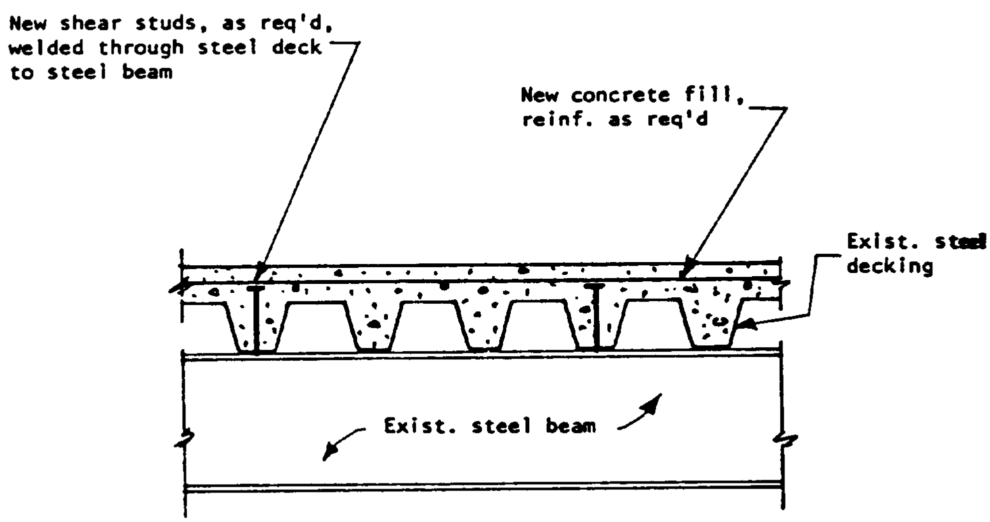


Figure 6–19. Strengthening of existing steel deck diaphragms

steel bracing system may be used as a diaphragm in existing buildings where the existing floor or roof system has not been designed for the required diaphragm action. This procedure will usually be limited to relatively flexible existing floor or roof systems such as timber or steel decking where the horizontal bracing can provide the necessary rigidity and transfer of the floor or roof shears to the vertical resisting elements. The bracing must be properly connected to the floor or roof system to pick up the inertia loads originating at that level and must include the necessary chords and connections to the vertical elements to provide the necessary out-of-plane support for these elements and to transfer the diaphragm shears to the resisting elements. Figure 6-27 indicates the use of horizontal bracing system in an existing steel frame building with concrete walls. It may not be necessary, in all cases, to provide crossbracing in all bays of the floor or roof system as shown in figure 6-27 if the existing system can be relied upon for some diaphragm action. The bracing configuration in figure 6-27 assumes negligible diaphragm capability (i.e., only adequate to transfer inertia forces between adjacent horizontal framing members) in the existing floor system.

(5) *External buttresses.* The use of external buttresses of reinforced concrete or braced structural steel could be feasible for strengthening an existing building. The buttresses may be designed to resist compressive forces only, in which case they must be located on both sides of the building in each direction to be braced. If the building has a structurally adequate diaphragm, the members and location of the buttresses will be determined to resist the calculated seismic forces and to minimize torsion. If the building has a flexible diaphragm, the buttresses must be designed for the tributary seismic forces and must be located where the existing framing can transfer the tributary loads by strut action. For example, in an existing steel frame building with a flexible diaphragm, the girders in the transverse direction may be assumed as receiving the seismic inertia loads from the secondary floor beams connected to the girders and buttresses would be located at each girder line. In the longitudinal direction, a similar assumption would be made regarding the secondary beams and buttresses would be located at every third or fourth beam assuming the existing floor system is capable of transferring the tributary floor loads. Buttresses that are designed to resist both tensile or compressive forces may be located on only one side of the building in each direction, but will require an adequate connection to be made to the existing building to transfer the tensile forces to the buttress. Figure 6-28 indicates the use of braced structural steel buttresses to strengthen an existing reinforced concrete building.

(6) *Structural additions.* An existing deficient building may be strengthened by a structural building addition that is designed to resist the seismic forces generated within the addition as well as all or a portion of the forces from the existing building. This alternative has the obvious advantage of generating additional useful space while upgrading the existing building. The design considerations are similar to those indicated in the above paragraph for buttresses except that the additional seismic forces from the new addition also have to be considered in the design of the resisting elements.

6-5. Upgrading of nonstructural elements

The evaluation of the adequacy of supports, anchorages, or bracing of nonstructural elements to resist the imposed seismic forces and displacements in existing buildings will be based on the results (story accelerations and interstory drifts) of the initial detailed structural analysis of the building or, if extensive structural modifications are required, on the subsequent reanalysis of the recommended concept. Analytical and acceptance criteria for these elements are provided in chapter 9 with typical details for seismic upgrading. Elements to be evaluated for upgrading will include:

a. Mechanical/electrical equipment (i.e., emergency motor generators, heating, air conditioning, and ventilation systems, electrical control panels, elevators, water and sewer lines, and sprinkler piping).

b. Suspended ceilings and light fixtures.

c. Nonstructural partitions.

d. Structural appendages (i.e., penthouses, parapets, canopies, and precast concrete curtain wall units).

e. Glazing (i.e., large glass panels).

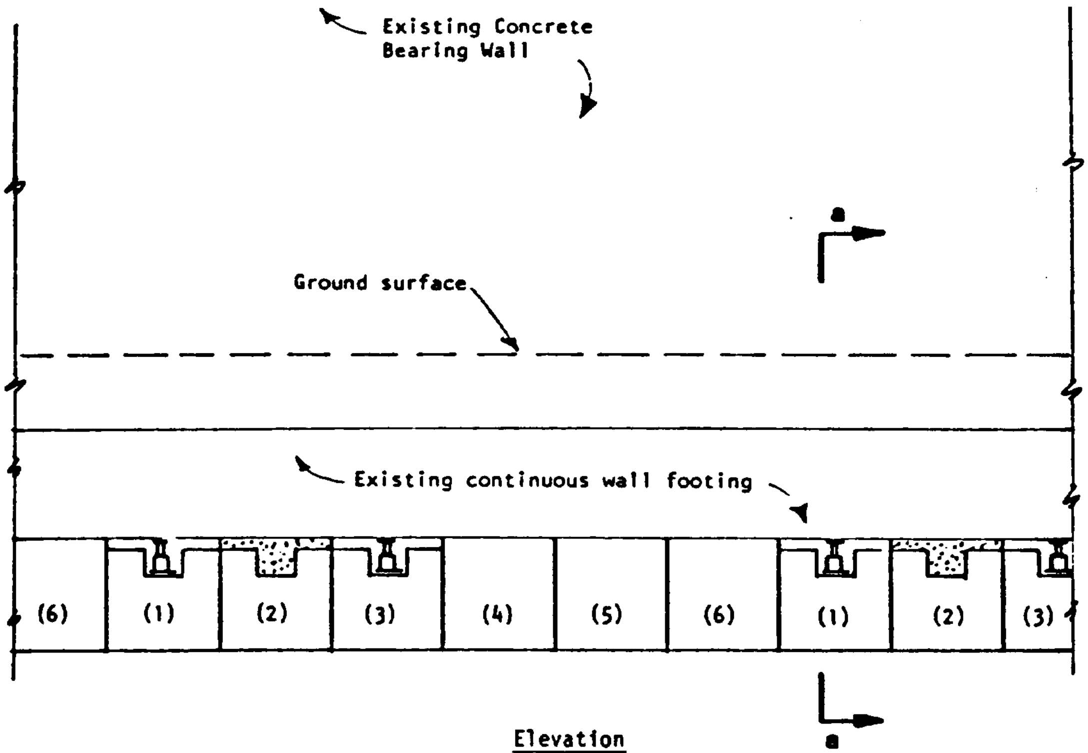
f. Miscellaneous (i.e., computer floors and freestanding storage units).

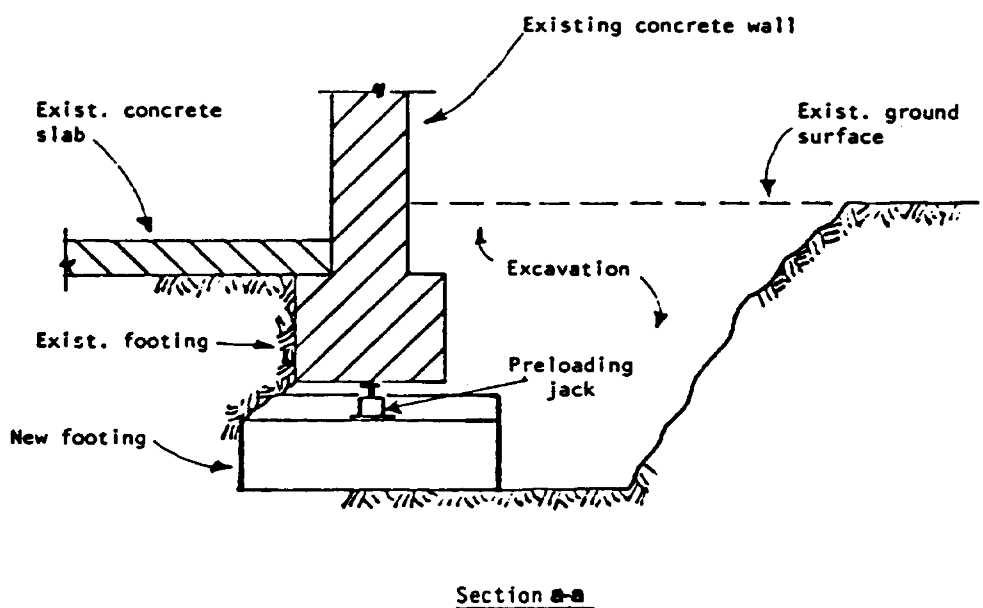
g. Storage shelving (i.e., supporting hazardous or essential items).

6-6. Concept submittal

A concept submittal will be prepared for review and approval by the approval authority. The submittal will comply with agency standards and will generally represent 25 to 35 percent of the effort required to complete the design of normal projects. The concept submittal will include the following elements:

a. Basis for design. This will include the acceptance and design criteria; a summary description





Sheet 1 of 2

Figure 6–20. Underpinning of an existing footing. (Sheet 1 of 2)

Construction Sequence:

1. Perform excavation and underpinning sequentially in widely spaced segments as shown [e.g. segments designated (1)].

2. Pour new concrete footing with jacking pocket and gap for drypacking.

3. When new concrete in (1) has attained adequate strength, place jacks to preload footing.

4. Repeat procedure for segments (2) and (3).

5. When jacks have been placed and loaded for (1), (2), and (3), drypack (2) and remove jack.

6. Proceed with remaining segments until complete footing is underpinned.

Sheet 2 of 2

Figure 6–20. Underpinning of an existing footing. (Sheet 2 of 2)

of the deficiencies identified in the detailed structural analysis; a narrative description of the alternative upgrading concepts; and justification for the recommended concept.

b. Calculations. Edited, checked, and indexed calculations will be included in the submittal to support the design of the upgrading concepts.

c. Cost estimates. Comparative cost estimates for the alternative concepts and a complete preliminary cost estimate for the recommended concept.

d. Schematic drawings. Schematic drawings will be prepared for the recommended concept. The drawings must be adequate to describe the nature, extent, and location of work required and, as a minimum, will include foundation and framing plans, typical sections, and typical connection details.

e. Outline specifications. Outline specifications will be prepared to describe the type and grade of structural material and procedures by reference to standard or industry specifications.

f. Schedules. The concept submittal will include the estimated number of man-hours to complete the design and estimated schedules (calendar days) for the design submittals, reviews, bidding, contract award, and construction.

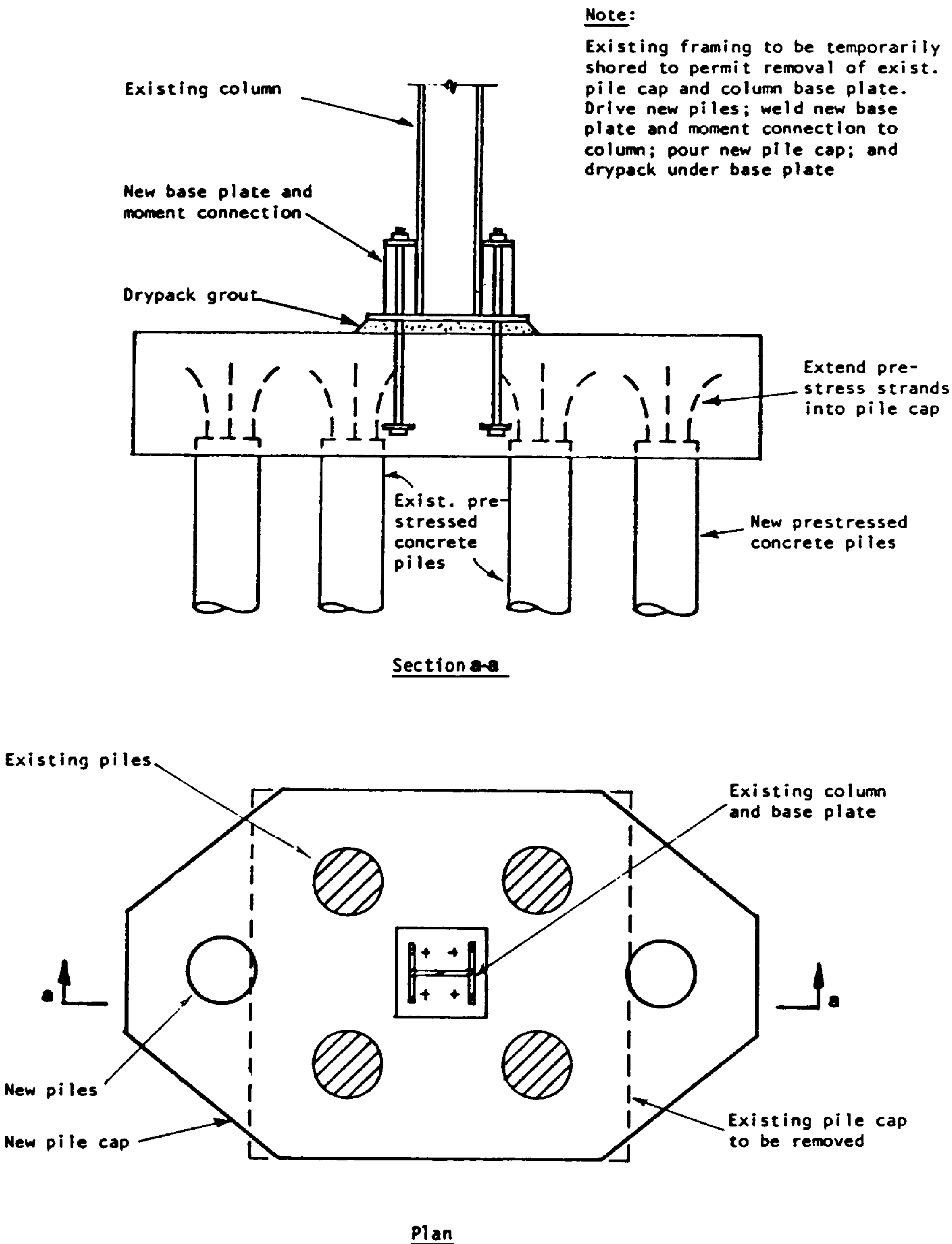
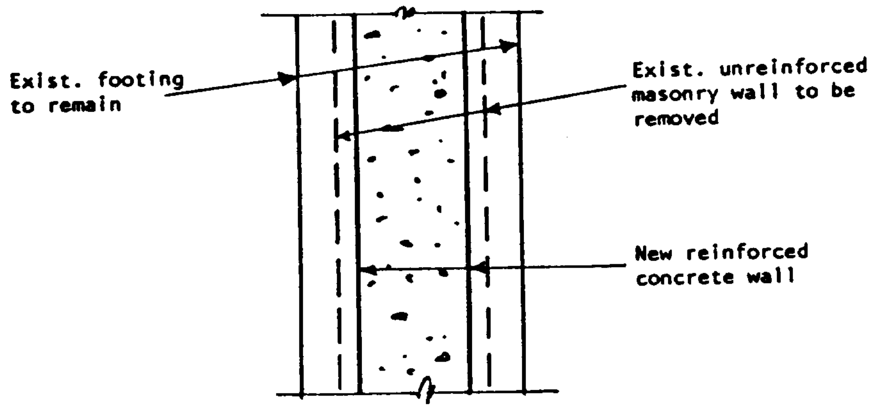
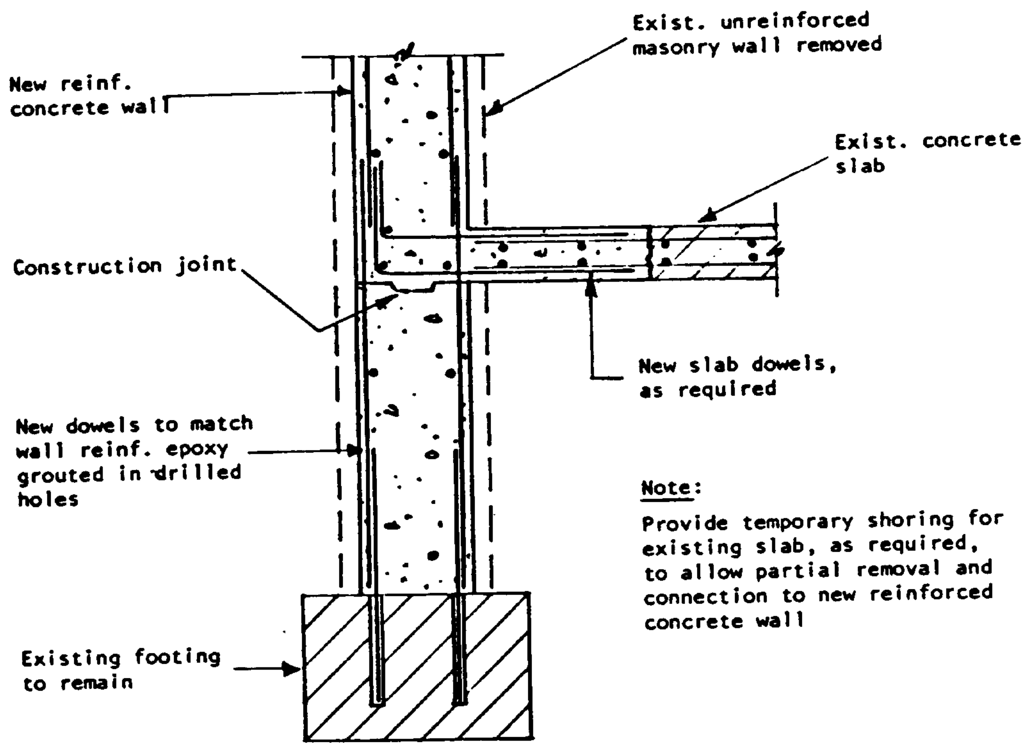


Figure 6–21. Upgrading of an existing pile foundation

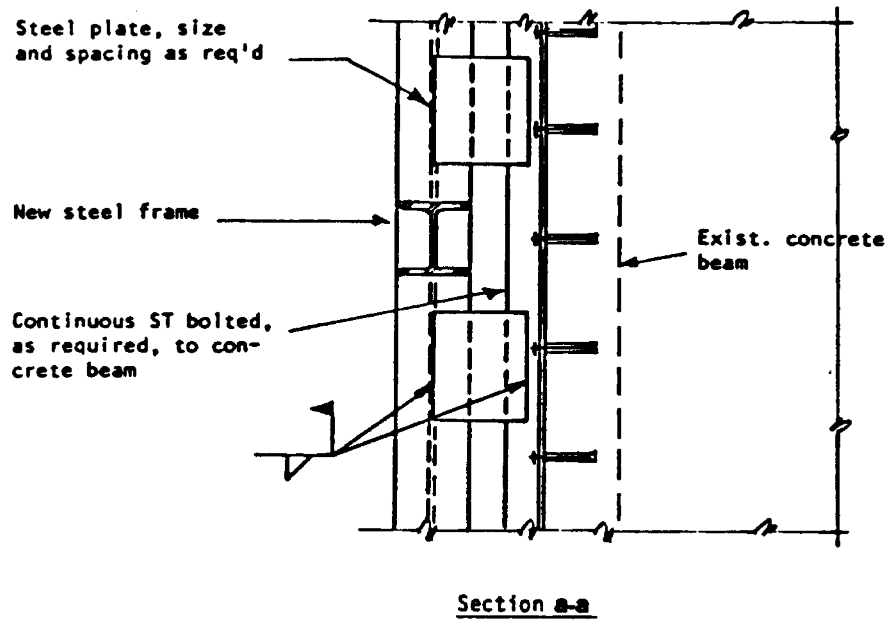


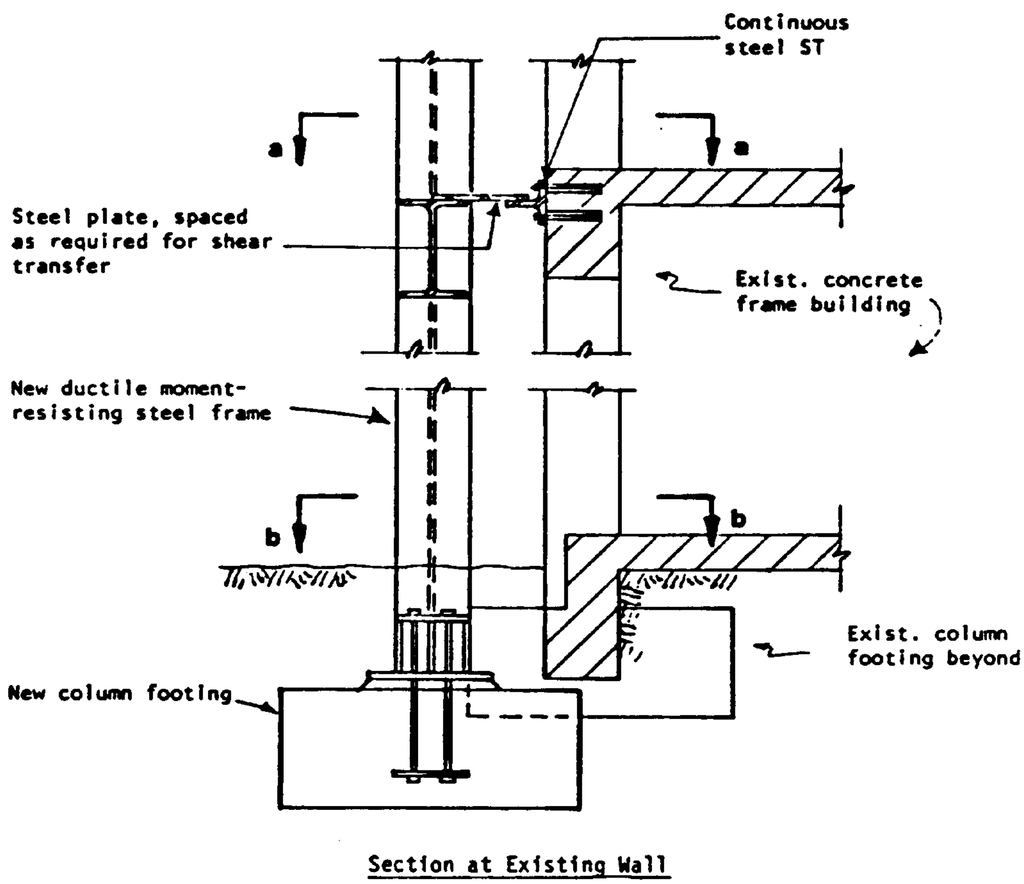
Plan



Section

Figure 6–22. Removal and replacement of an unreinforced masonry wall





Sheet 1 of 2

Figure 6–23. Upgrading an existing building with external frames. (Sheet 1 of 2)

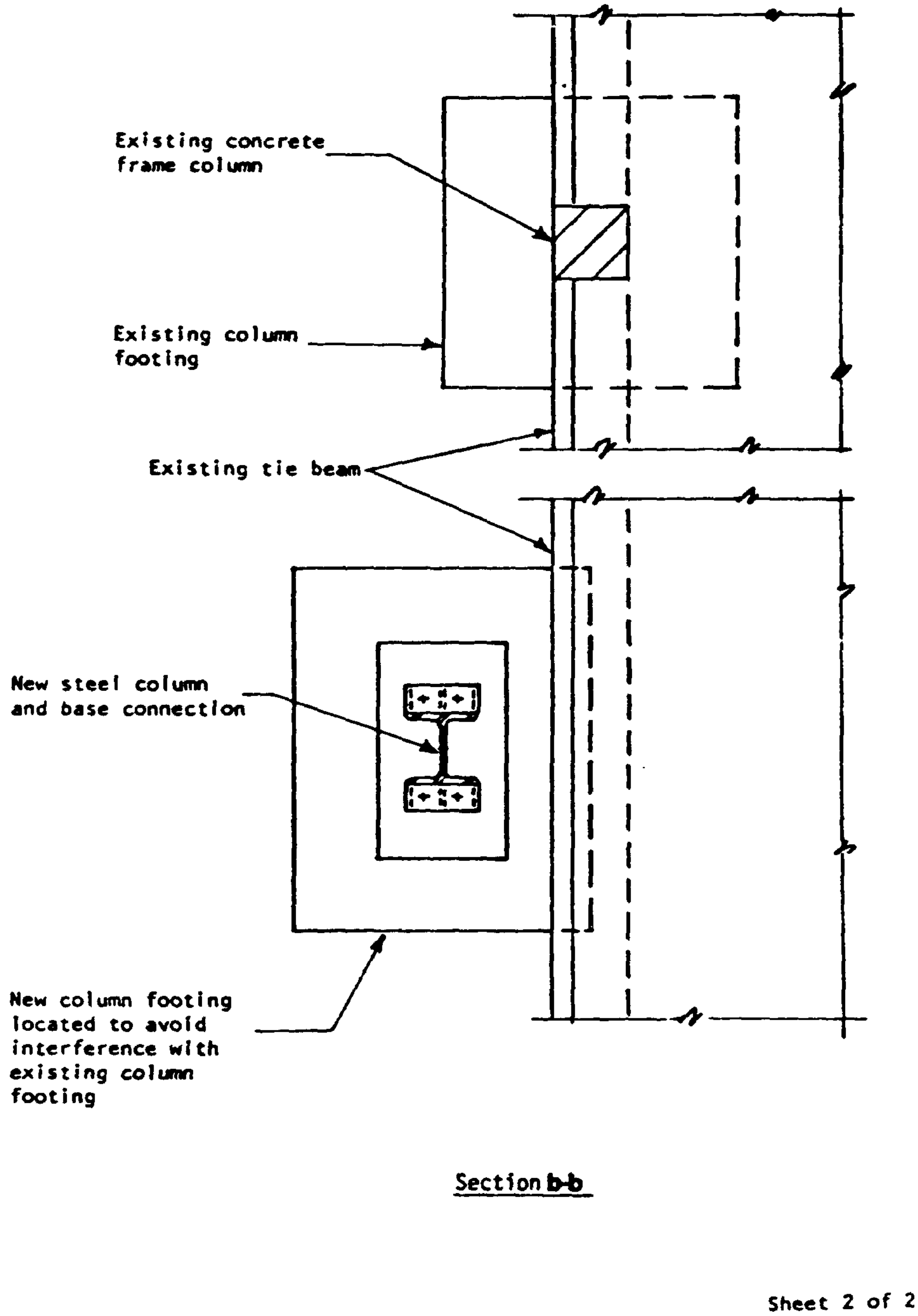


Figure 6–23. Upgrading an existing building with external frames. (Sheet 2 of 2)

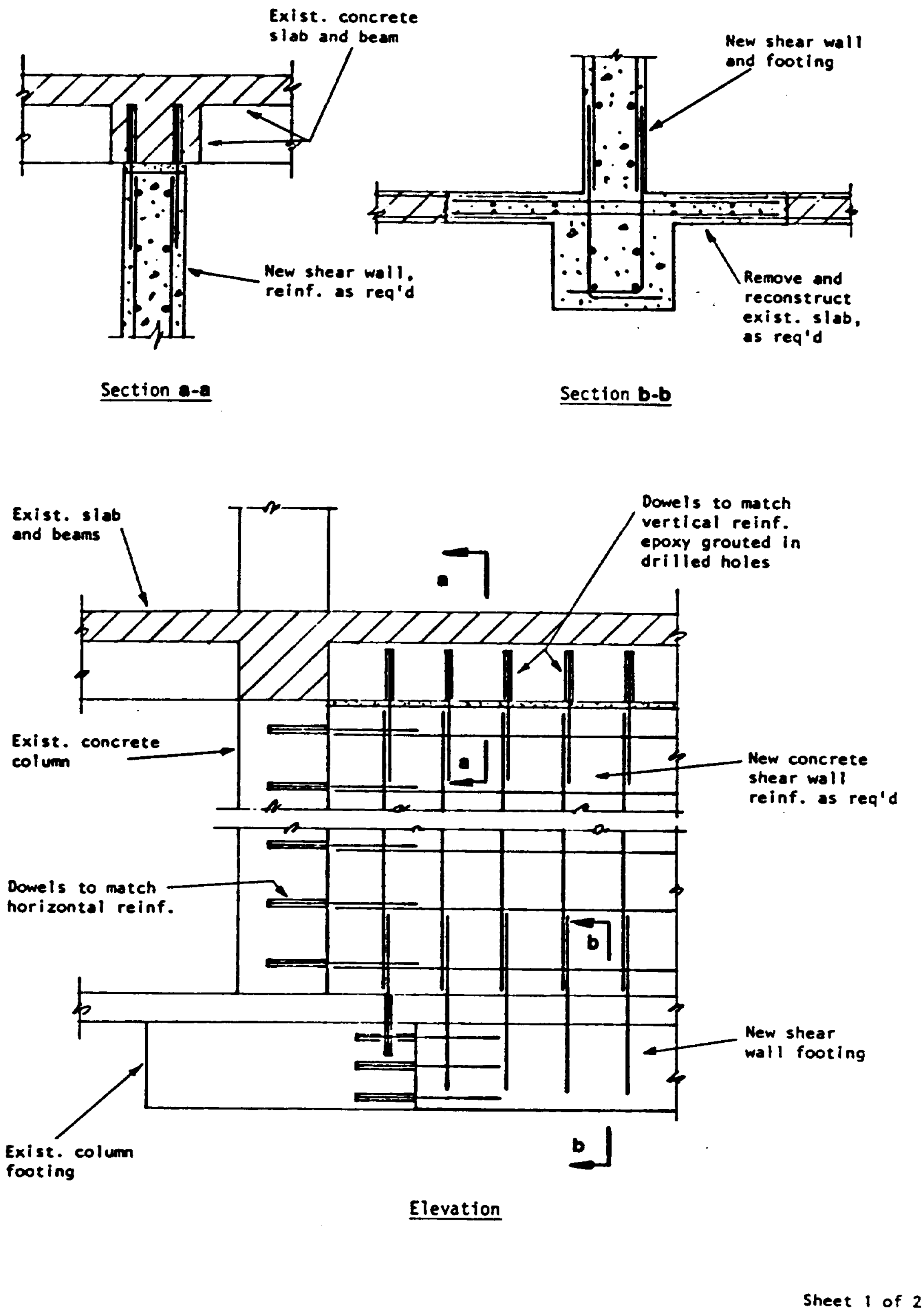
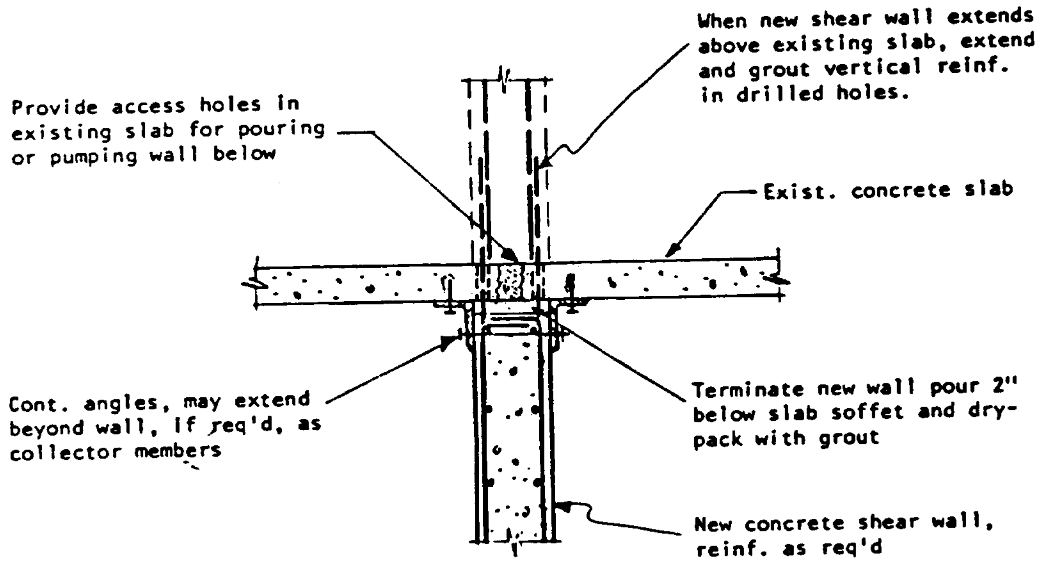


Figure 6–24. Strengthening of an existing concrete frame building with a reinforced concrete shear wall. (Sheet 1 of 2)



Detail

New Concrete Shear Wall
at Existing Slab

Sheet 2 of 2

Figure 6-24. Strengthening of an existing concrete frame building with a reinforced concrete shear wall. (Sheet 2 of 2)

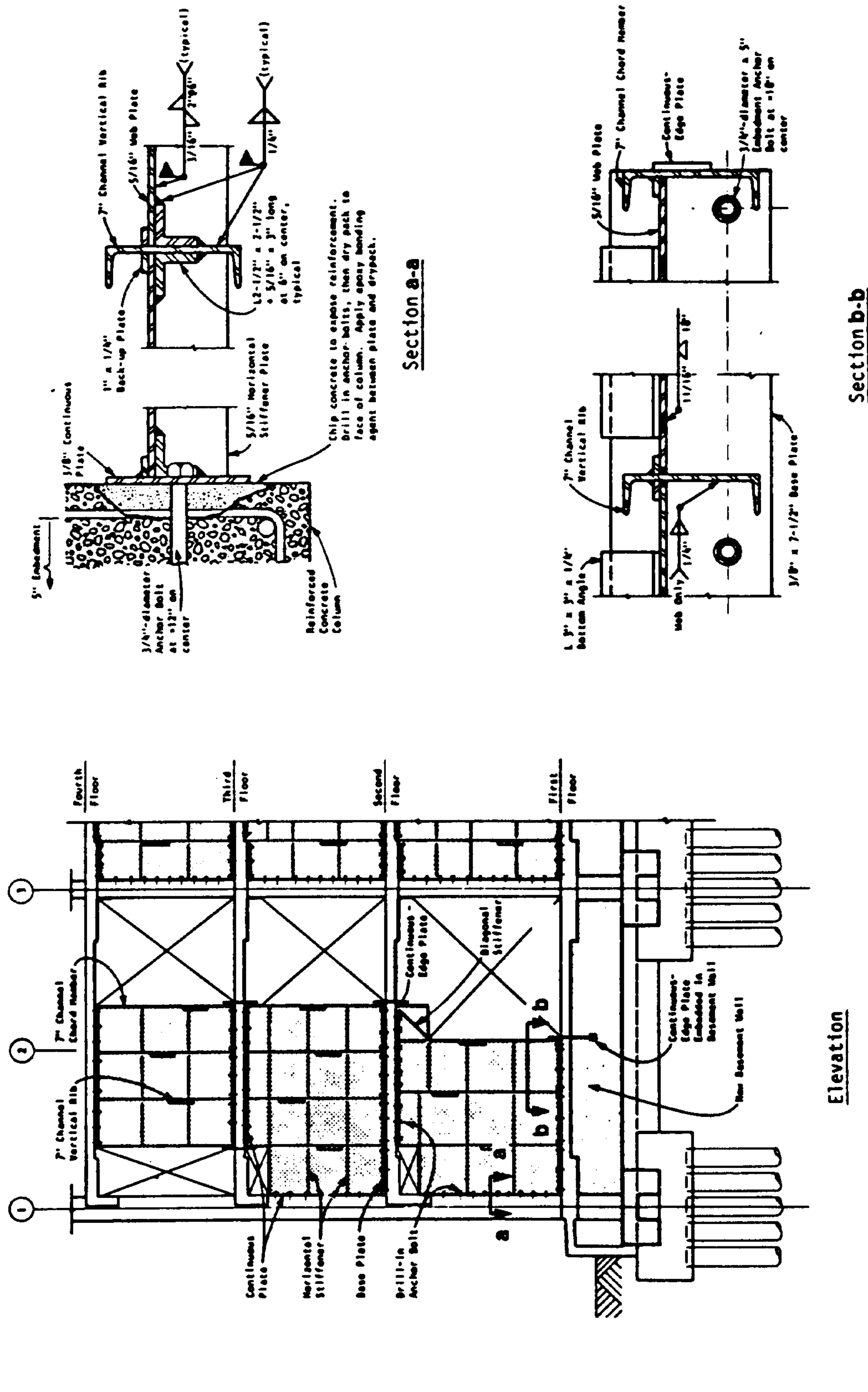
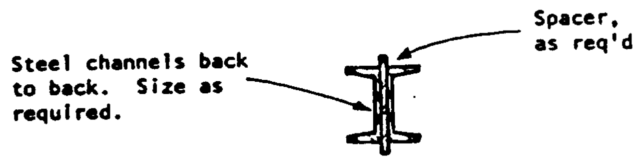
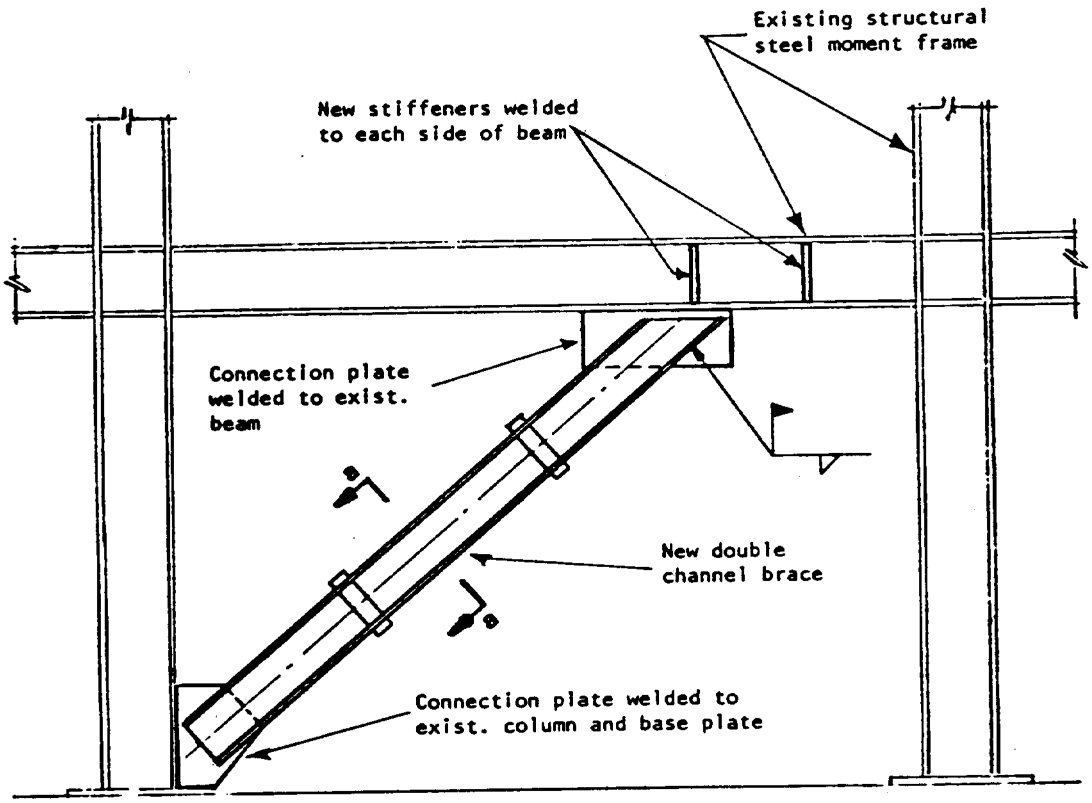


Figure 6-25. Steel shear wall in an existing building



Section a-a



Elevation

Figure 6–26. Strengthening of an existing building with eccentric bracing

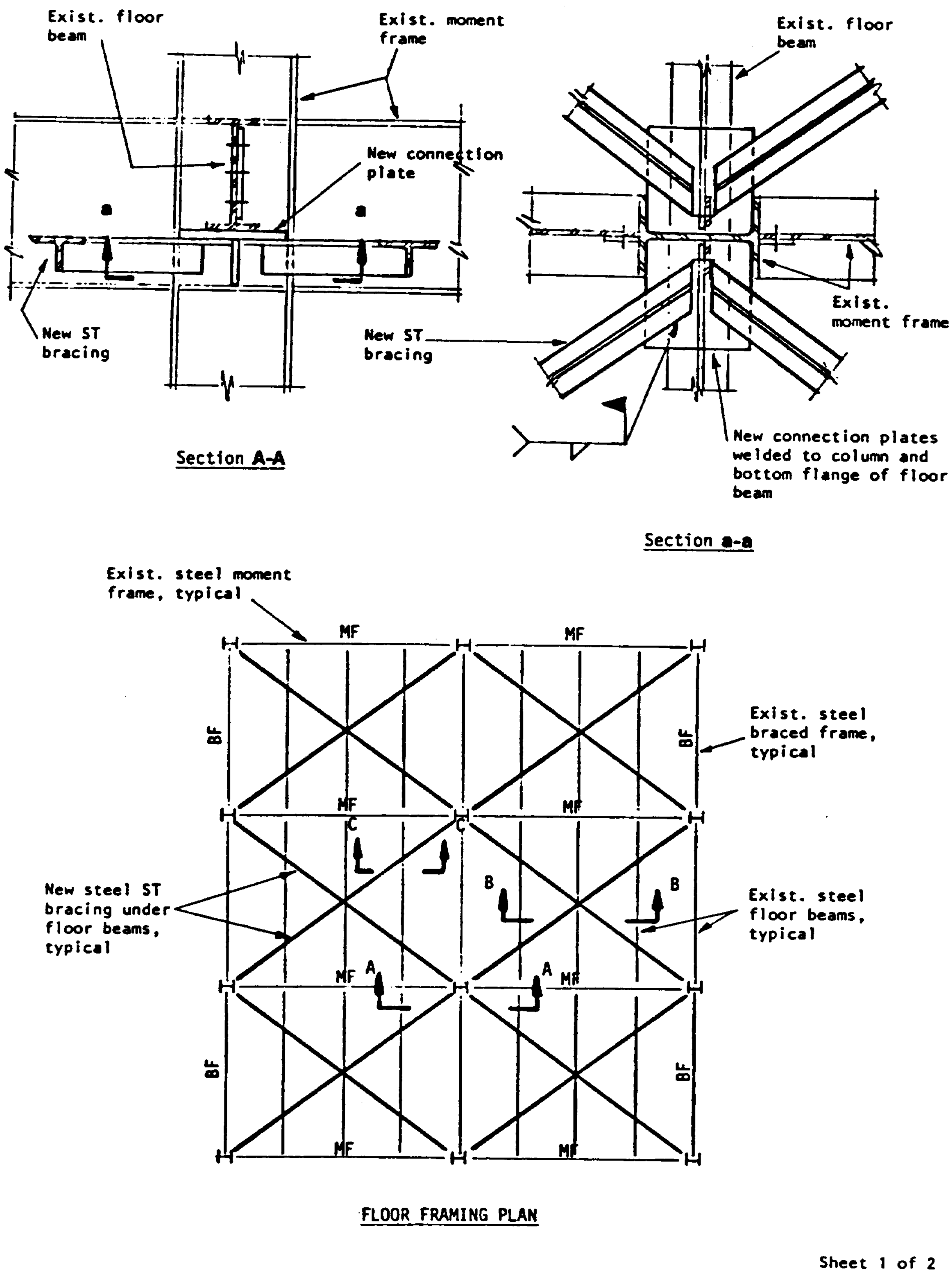
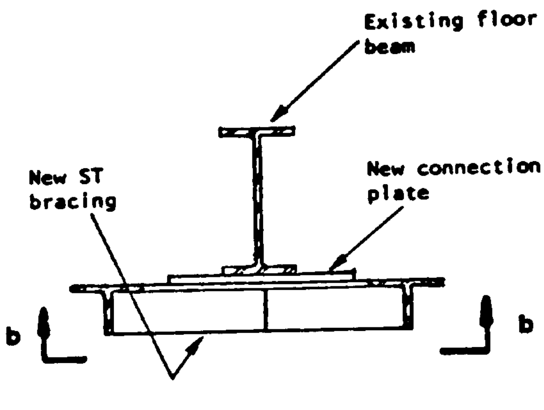
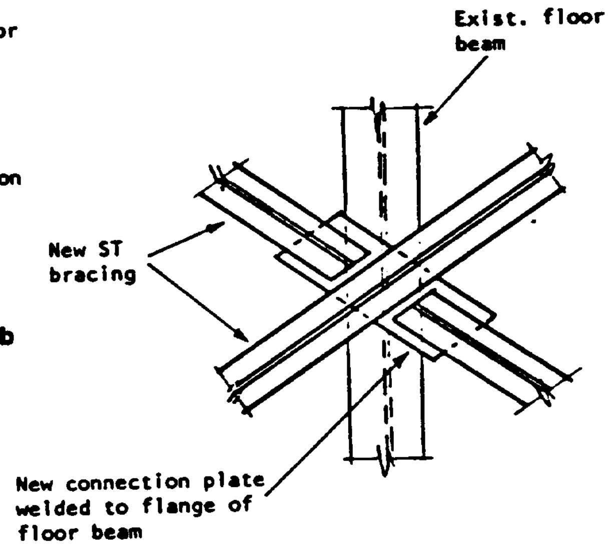


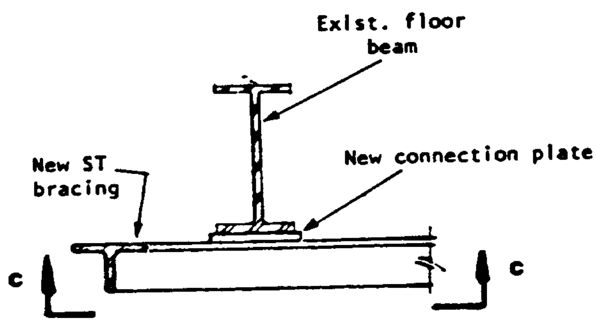
Figure 6–27. Strengthening of an existing steel frame building with horizontal bracing. (Sheet 1 of 2)



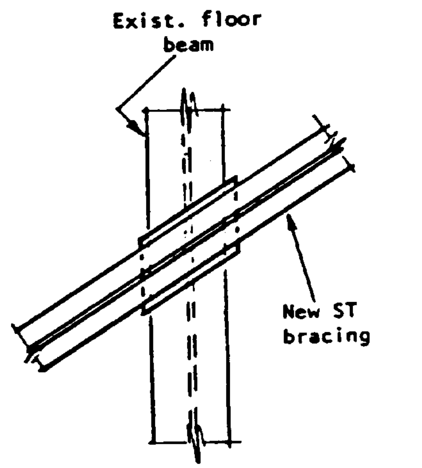
Section B-B



Section b-b



Section C-C



Section c-c

Sheet 2 of 2

Figure 6–27. Strengthening of an existing steel frame building with horizontal bracing. (Sheet 2 of 2)

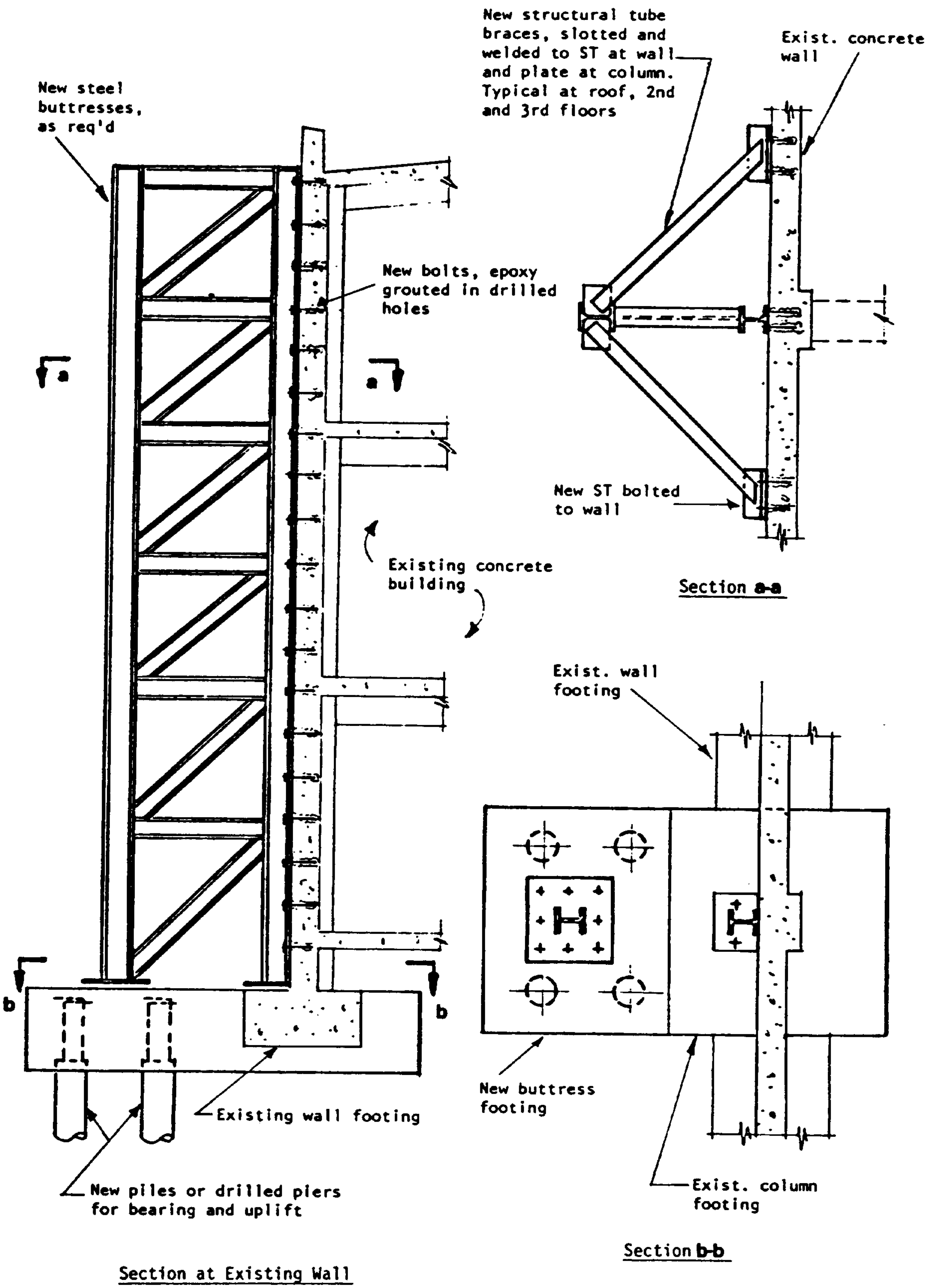


Figure 6–28. Braced structural steel buttresses to strengthen an existing reinforced concrete building